DLP® LightCrafter 4500™ Evaluation Module

User's Guide

Literature Number: DLPU011B
July 2013–Revised October 2013

Contents

List of Figures

List of Tables

Read This First

About This Guide

The DLP® LightCrafter 4500™ is a third-party implementation of the next generation DLP reference design to enable faster development cycles for applications requiring small form factor and intelligent pattern display.

This guide is an introductory document for the DLP LightCrafter 4500 that provides an overview of the system and its software. Other documents provide more in-depth information of the hardware and software features of the components of the DLP LightCrafter 4500.

DLP LightCrafter 4500 Evaluation Module (EVM)

Related Documentation From Texas Instruments

DLPC350 Datasheet: *DLP Digital Controller for the DLP4500 DMD*, DLPS029

DLP4500 Datasheet: *DLP 0.45 WXGA DMD*, DLPS028

DLPC350 and DLP4500 Chip Set Manual: *DLP 0.45 WXGA Chip Set Data Manual*, DLPU009

User's Guide: *DLPC350 Programmer’s Guide*, DLPU010

Application Note: *Using DLP® LightCrafter 4500™ Triggers to Synchronize Camera*, DLPA036

If You Need Assistance

Refer to the DLP and MEMS TI E2E Community support forums: DLP LightCrafter 4500 Development Platform Forum

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DLP LightCrafter 4500 Module Overview

1.1 Welcome

The DLP LightCrafter 4500 module allows evaluation of TI's DLP 4500 platform.

This technology brings together a set of components providing an efficient and compelling system solution for:

- Structured light applications:
  - 3D modeling and design
  - Fingerprint identification
  - Face recognition
  - Machine vision and inspection
- Medical and life sciences:
  - Vascular imaging
  - Dental impression scanners
  - Intraoral dental scanners
  - Orthopaedics, prosthesis, CT, MRI, and X-ray marking
  - Retail cosmetics
- Small display projectors:
  - Embedded display
  - Interactive display
  - Information overlay

1.2 What is in the LightCrafter 4500 Evaluation Module (EVM)?

The DLP LightCrafter 4500 module consists of two subsystems:

- Light engine – includes the optics, red, green, and blue LEDs, and the 912 × 1140 diamond pixel 0.45 in. WXGA DMD, heat sinks, and fan. The light engine produces approximately 150 lumens at 15-W LED power consumption.
- Driver board – includes the LED driver circuits, DLPC350 DMD controller, power management circuits, DVI-to-RGB conversion with the TFP401, and a 32MB flash storage

Figure 1-1 shows the major hardware components.

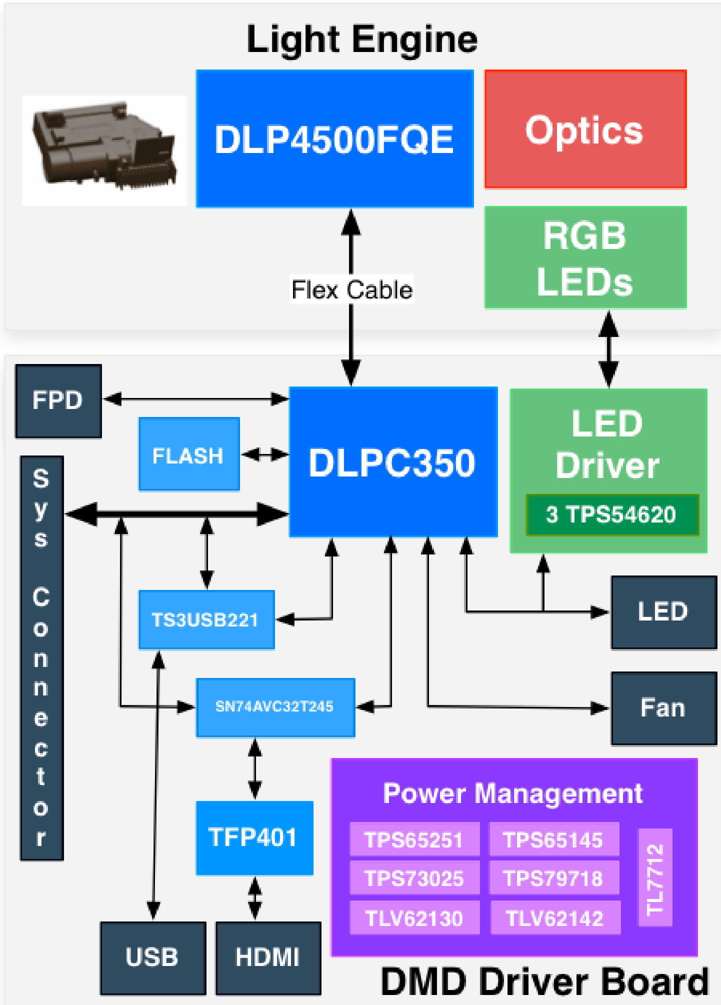


Figure 1-1. DLP LightCrafter 4500 Block Diagram

1.2.1 Light Engine

iView Limited developed the DLP LightCrafter 4500 Light Engine. As shown in Figure 1-2, the light engine includes:

- DLP4500FQE DMD
- DMD heat sink
- Red, green, and blue LEDs
- Focus control
- Projection lens

The iView Light Engine is mounted on top of a large thermal plate to cool the module. The DLP4500 DMD is mounted vertically between the DMD heat sink and the light engine. On the opposite side to the DMD, the red and green LEDs are mounted between a thermal plate and the light engine. The blue LED is mounted between a thermal plate and the light engine, next to the projection lens. An LED heat sink is mounted behind the red and green LED thermal plate and thermally connected to the blue LED thermal plate. A fan forces air across the LED heat sink to cool the LEDs.

The light engine, not including the LED heat sinks, has a length of 90.5 mm, width of 73.7 mm, and height of 23.6 mm.

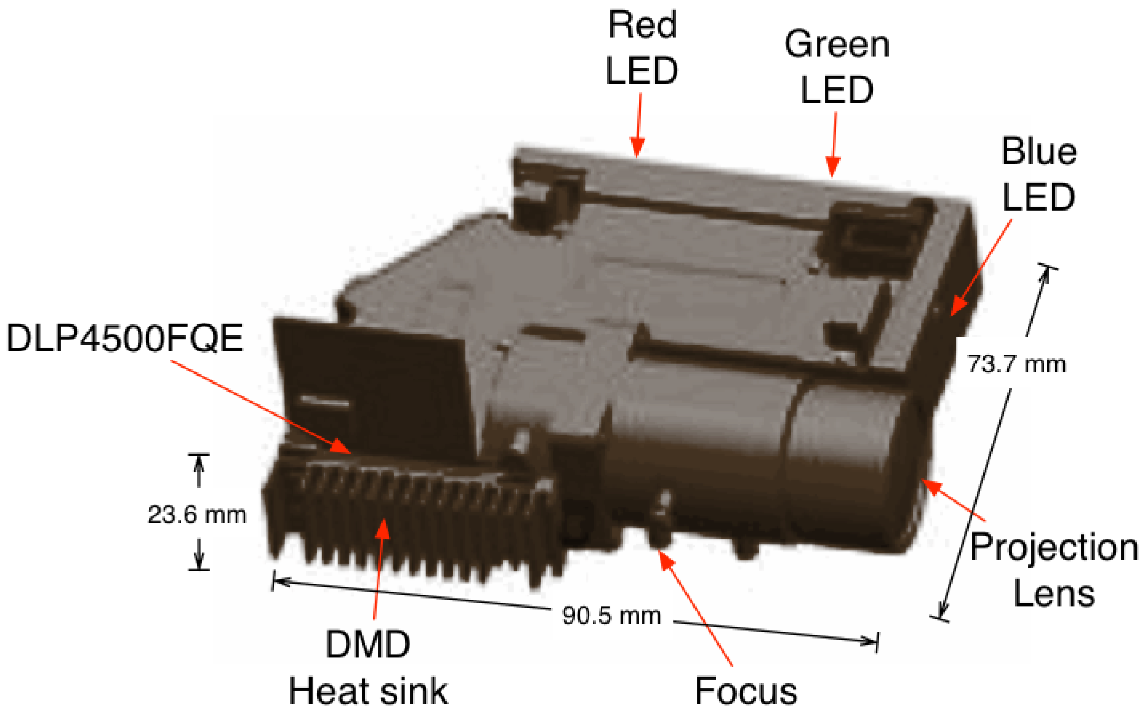


Figure 1-2. iView Light Engine

Table 1-1 lists the specifications of the light engine:

Table 1-1. DLP LightCrafter Light Engine Specifications

Parameter	MIN	TYP	MAX	UNIT
Brightness		150		lm
LED power consumption		15		W
Full-on full-off contrast		1000:1		
Uniformity	80	90		%
F-number		2.1		
Throw ratio		1.4		
Offset		100		%
Focus range	0.5	1	2	m
Image diagonal size	16.7	32.8	65	inch

The light engine includes the DLP4500 0.45-in. DMD with 1039680 mirrors, each 7.6 µm, arranged in 912 columns by 1140 rows with the diamond pixel array geometry and configuration shown in Figure 1-3 and Figure 1-4. Due to the diamond pixel configuration, the array produces smooth diagonal lines, with jagged vertical and horizontal lines, as shown in Figure 1-5. Two options exist to produce the vertical and horizontal lines: using every row or column, or skipping every other row or column. When every row or column is used, a thicker line is projected. When every other row or column is used, a fainter line is projected.

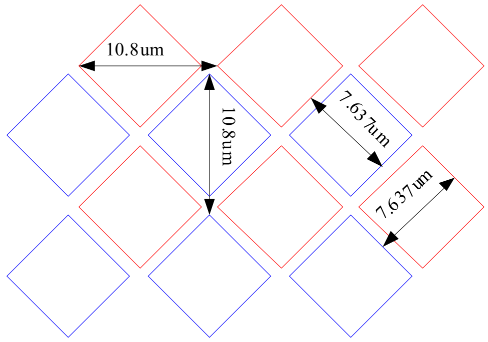


Figure 1-3. 0.45-in. DMD Diamond Pixel Geometry

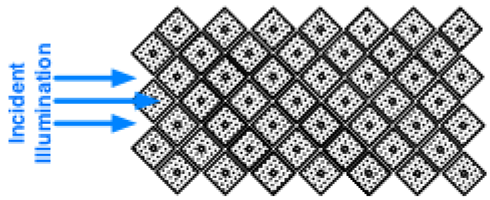


Figure 1-4. 0.45-in. DMD Diamond Pixel Array Configuration

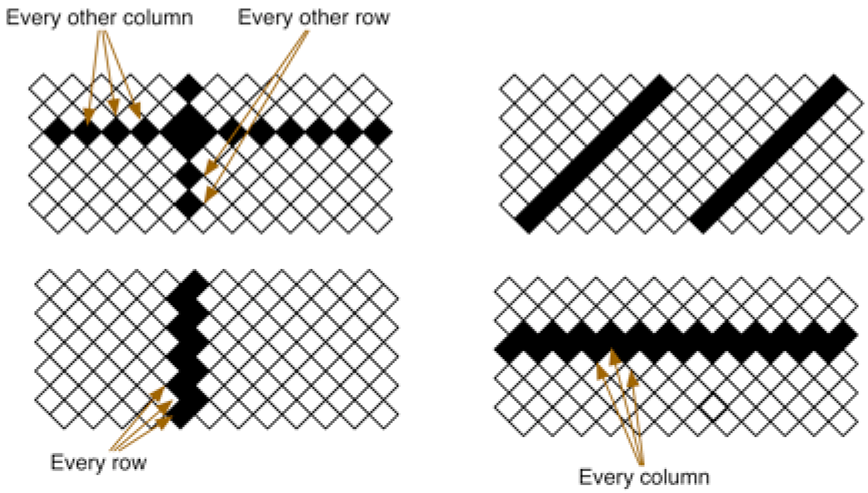


Figure 1-5. Diamond Pixel for Vertical, Horizontal, and Diagonal Lines

1.2.1.1 Light Engine Thermal Limits

The DLP LightCrafter 4500 is an actively cooled system with a thermal limit requiring that the total of all three simultaneous LED currents are less than 4.3 A.

CAUTION

Do not overheat the system by driving all LEDs at maximum power.

1.2.2 Driver Board

The DLP LightCrafter 4500 driver board contains the electronics to drive the DLP4500 DMD, LEDs of the light engine, and the LED cooling fan. It offers several interface options for USB, I2C, trigger inputs and outputs, video input through mini-HDMI and FPD-link connector, and a system board interface. Figure 1-6 shows the driver board block diagram of the DLP LightCrafter 4500.

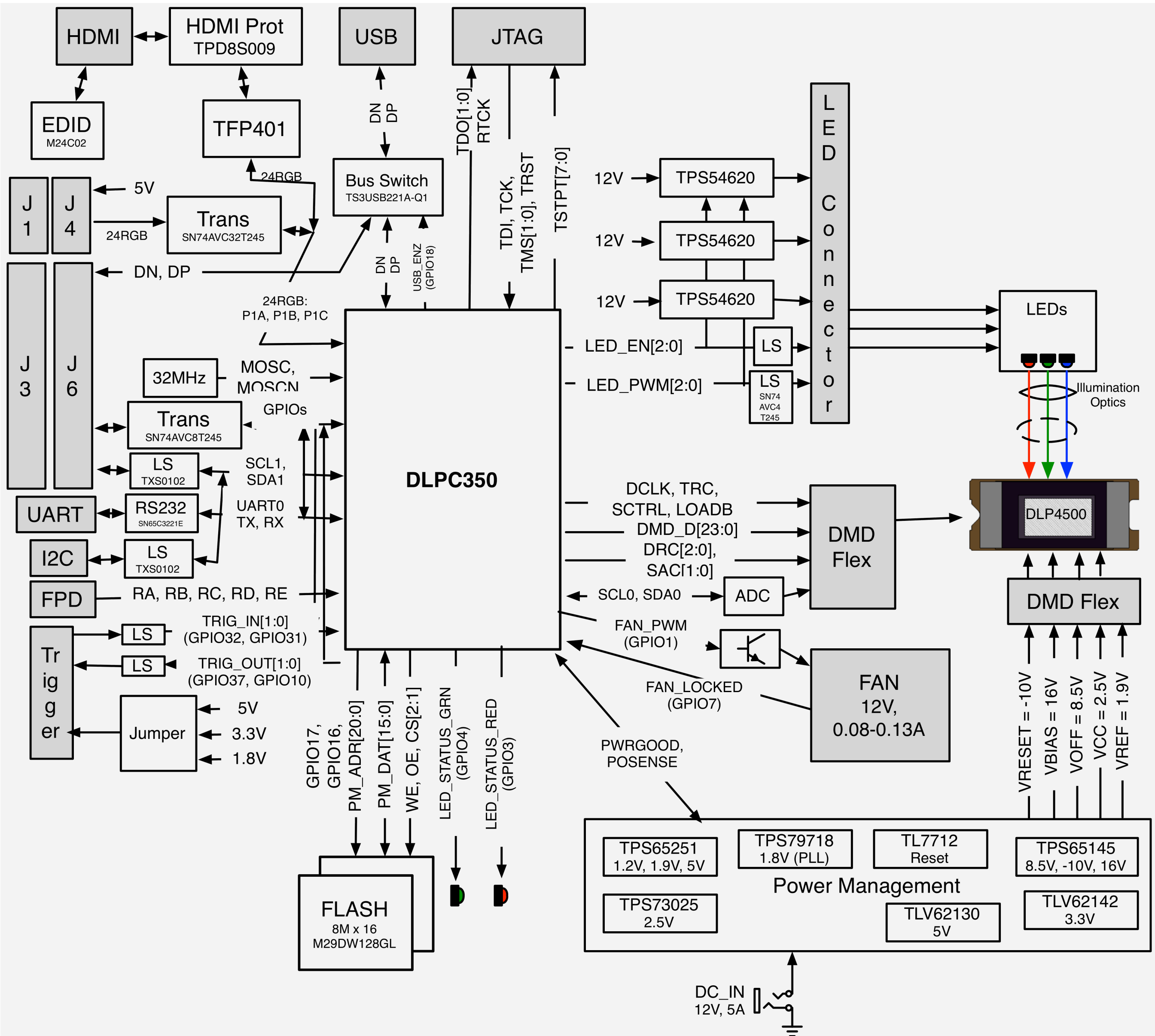


Figure 1-6. DLP LightCrafter 4500 Driver Board Block Diagram

The DLP LightCrafter 4500 driver board major components are:

- DLP4500: 0.45 in.-WXGA DMD
- DLPC350: DLP4500 controller
- 32MB parallel FLASH contains DLPC350 firmware and 24-bit compressed images
- TPS54620: Synchronous step-down converter serving as an LED driver capable of driving up to 5 A per LED
- Power management:
  – TPS65251: Triple output buck switcher for DLPC350 1.2-V and 1.9-V supplies and 5-V board

supply.
  - TPS65145: Triple output boost converter for DLP4500 8.5-, –10-, and 16-V supplies
  - TPS73025: Step-down converter for DLP4500 2.5-V supply
  - TLV62130: Step-down converter for 3.3-V supply
  - TLV62130: Step-down converter for 5-V system board supply
  - TPS79718: LDO for DLPC350 1.8-V analog supply
  - TL7712: Programmable time delay for power-supply sequencing
- TFP401: Digital Receiver for DVI to 24-bit parallel RGB interface
- TS3USB2221A: ESD-protected high-speed USB multiplexer
- SN74AVC32T245: 32-bit dual supply bus transceiver for system board interface

1.2.3 System Board

The DLP LightCrafter 4500 driver board allows the connection of a PandaBoard 4500. See Chapter 6

1.3 Other items needed for operation

The DLP LightCrafter 4500 module is a flexible, ready-to-use evaluation module (EVM). However, the DLP LightCrafter 4500 EVM does not ship with cables, power supply, or additional hardware components. To use the EVM, the user needs:

- Power supply:
  - Nominal voltage: 12-V DC
  - Typical current: 5 A
  - Maximum current: 7 A
  - DC connector size:
    - Inner diameter: 2.5 mm
    - Outer diameter: 5.5 mm
    - Shaft: 9.5-mm female, center positive
  - Efficiency level: V
  - A recommended power supply is Digi-Key part number 271-2718-ND, or equivalent
- USB cable: A to mini-B USB cable
- Optional: PandaBoard 4500

1.4 DLP LightCrafter 4500 Connections

Figure 1-7 and Figure 1-8 depict the switches and connectors with their respective locations. Note that no cables, nor power supply are included with the unit.

1. Reset button
2. Power connector: Use a power supply with a 12-V DC output with 5 to 7-A current rating and a plug of 2.5 mm inner diameter × 5.5 mm outer diameter and 9.5-mm female center positive shaft. The current output of the power supply determines how much current the LED driver can supply
3. External trigger output connector: Supports two trigger output signals, each with configurable voltage of 5 V, 3.3 V, and 1.8 V through jumpers, J13 and J15
4. Mini-USB connector: use an A to mini-B USB cable to connect to a PC
5. UART/RS232 mini-plug connector output: DLPC350 3.3-V UART output for error messages. Mini-plug tip is DLPC350 transmit (TX) and ring is DLPC350 receive (RX) signals. UART has the following serial configuration:
   - Bits per second: 115200
   - Data bits: 8
   - Parity: None
   - Stop bits: 1
   - Flow Control: None
6. External trigger Input connector: Supports two trigger input signals, each with configurable voltage of 5 V, 3.3 V, and 1.8 V through jumpers, J10 and J12
7. Stand-by switch: Places the DLP LightCrafter 4500 in standby mode, powering down the LED Driver and the DLPC350
8. Flat panel display-link connector
9. Fan connector
10. Red LED supply connector (bottom of the board)
11. DLPC350 I2C1 bus
12. DLPC350 I2C0 bus
13. Green LED supply connector
14. Blue LED supply connector
15. External LED driver connector: Insert a jumper in J30 to disable the DLP LightCrafter 4500 LED drivers and set jumper J28 for 3.3-V or 1.8-V supply. Then use this connector to control an external LED driver board to power the LEDs of the DLP LightCrafter 4500 light engine or external light engine.
16. System board connector: This interface routes USB, I2C, GPIO, and triggers from DLPC350 to a system board to control the DLP LightCrafter 4500.
17. Focus control (bottom of the board): Adjust focus from 0.5 m to infinity
18. JTAG connector for DLPC350
19. JTAG Boundary Scan for DLPC350 (bottom of the board)
20. DVI input through mini-HDMI connector (bottom of the board). This input supports resolutions of 1280 × 800, 1024 × 768, 1024 × 640, 912 × 1140, 800 × 600, 800 × 500, and 640 × 480 at 60 Hz. In *Video Mode*, the DLPC350 scales the input resolution to the native resolution of the DLP4500 DMD. In *Pattern Sequence* mode, this input supports 912 × 1140 resolution.

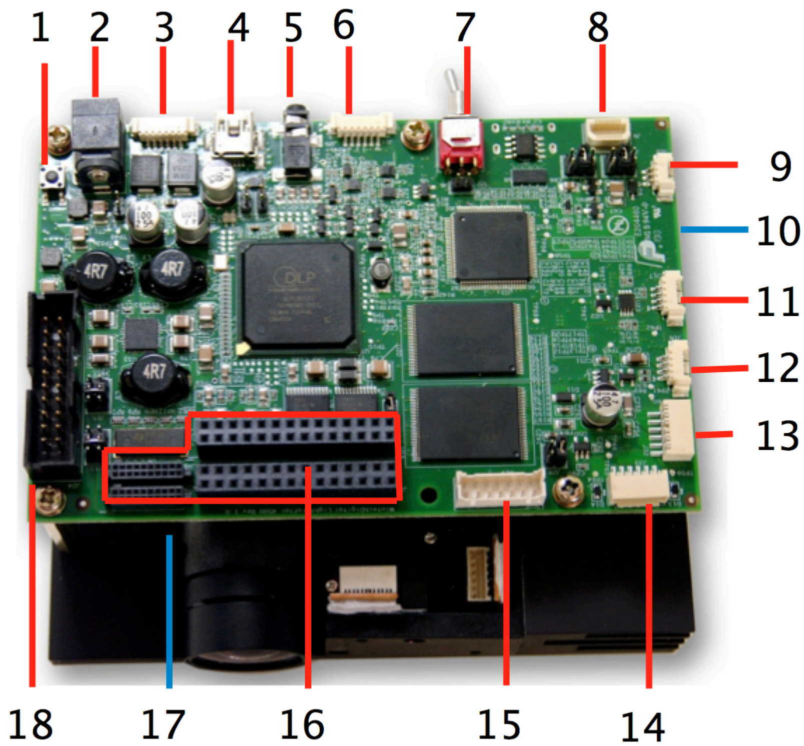


Figure 1-7. DLP LightCrafter 4500 Connectors (Top View)

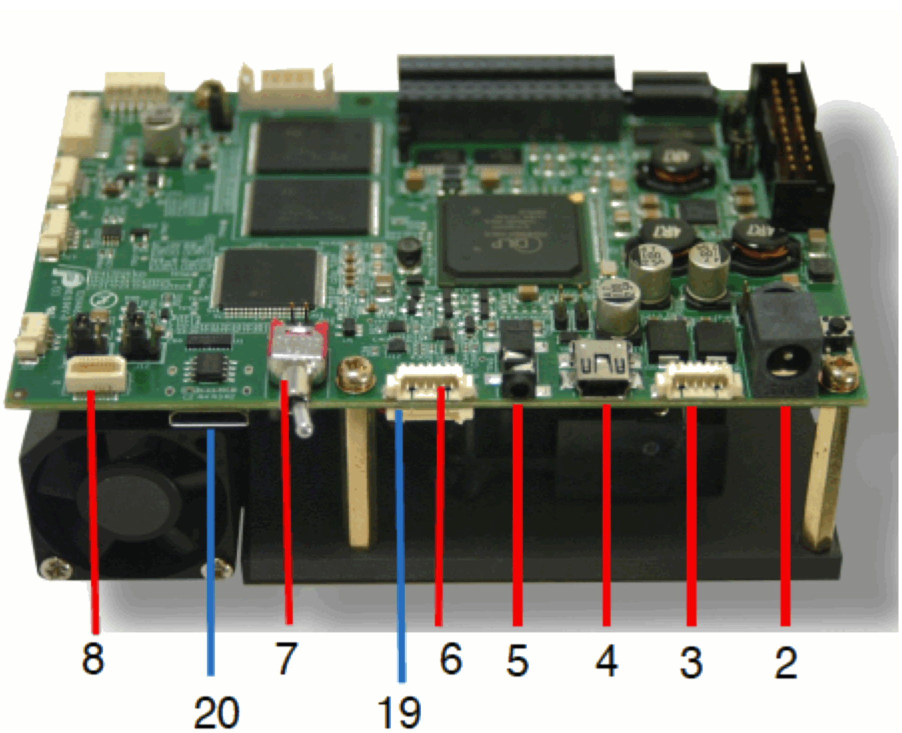


Figure 1-8. DLP LightCrafter 4500 Connectors (Back-Side View)

1.5 DLP LightCrafter 4500 Jumpers

The DLP LightCrafter 4500 has jumper options to disable the on-board LED driver, control voltages of the LED signals to an external board, and control the trigger input and output voltages. This section lists all the jumpers on the DLP LightCrafter 4500 driver board. Figure 1-9 depicts the locations of these jumpers. These jumpers require a 2-mm jumper, like Sullins Connector Solutions® SPN02SYBN-RC, Digi-Key part number S3404-ND.

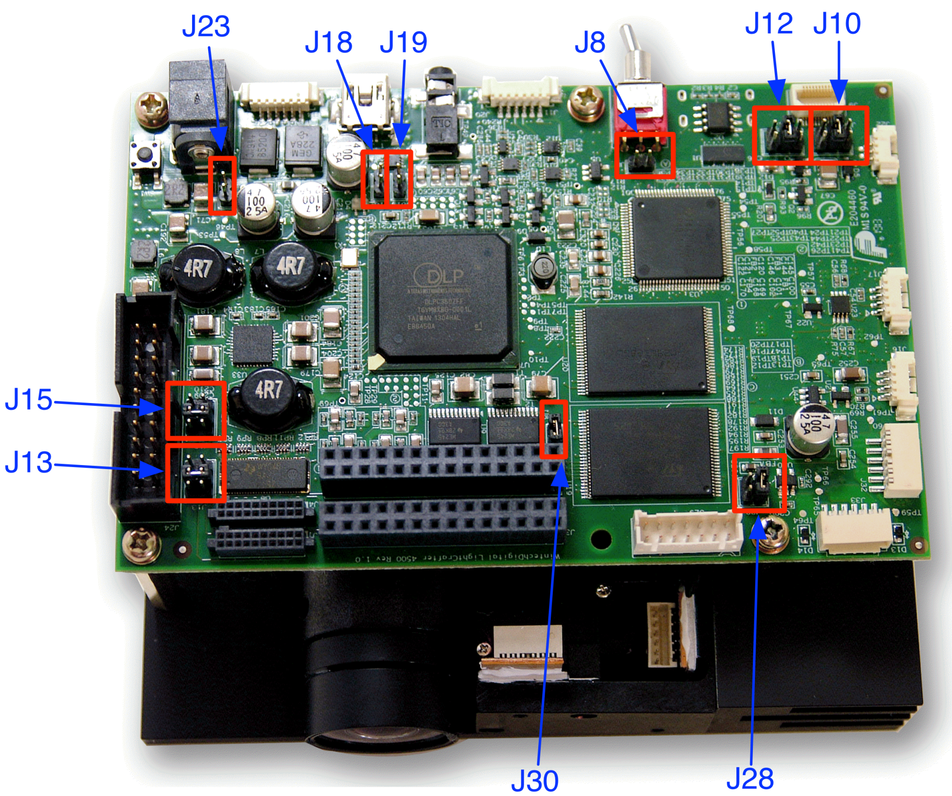


Figure 1-9. DLP LightCrafter 4500 Jumper Locations

- J8: EDID write protect disable jumper. Place this jumper to reprogram the EDID EEPROM (U2) using I2C commands through the mini-HDMI connector. Remove the jumper when programming of the EDID is complete. The EDID is programmed at the factory with resolutions of 1280 x 800, 1024 x 768, 1024 x 640, 912 x 1140, 800 x 600, 800 x 500, 640 x 480.
- J10: DLPC350 TRIG1_IN voltage selection. Refer to Figure 1-10.
  - Jump across pins 1 to 2 for 5 V
  - Jump across pins 3 to 4 for 3.3 V
  - Jump across pins 5 to 6 for 1.8 V
- J12: DLPC350 TRIG2_IN voltage selection. Refer to Figure 1-10.
  - Jump across pins 1 to 2 for 5 V
  - Jump across pins 3 to 4 for 3.3 V
  - Jump across pins 5 to 6 for 1.8 V

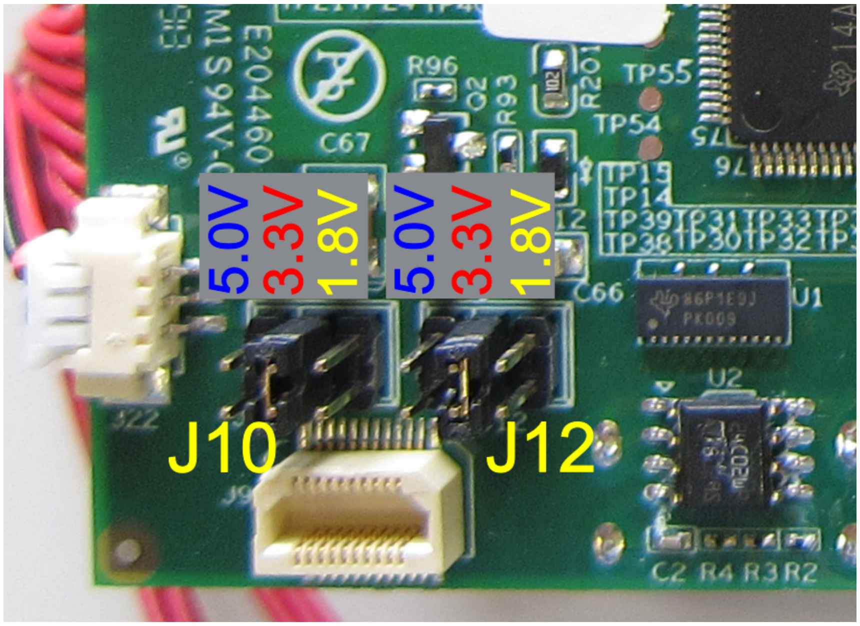


Figure 1-10. DLP LightCrafter 4500 J10 and J12 Voltage Jumpers

- J13: DLPC350 TRIG1_OUT voltage selection. Refer to Figure 1-11.
  - Jump across pins 1 to 2 for 5 V
  - Jump across pins 3 to 4 for 3.3 V
  - Jump across pins 5 to 6 for 1.8 V
- J15: DLPC350 TRIG2_OUT voltage selection. Refer to Figure 1-11.
  - Jump across pins 1 to 2 for 5 V
  - Jump across pins 3 to 4 for 3.3 V
  - Jump across pins 5 to 6 for 1.8 V

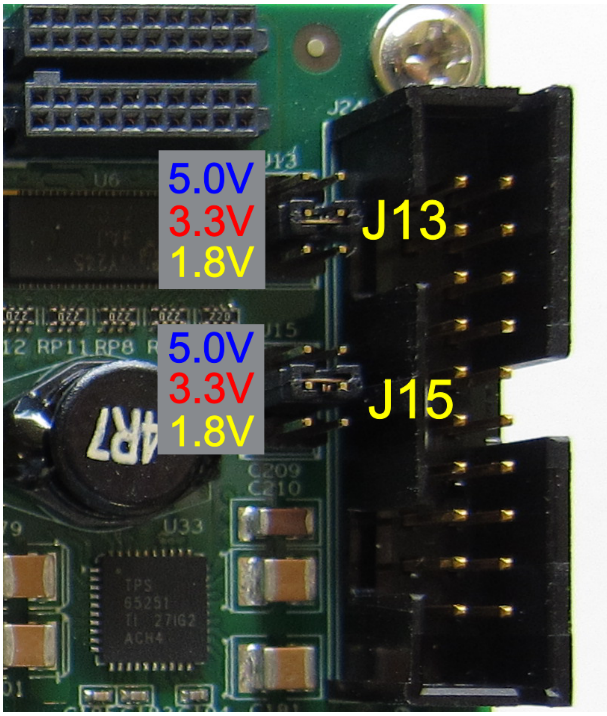


Figure 1-11. DLP LightCrafter 4500 J13 and J15 Voltage Jumpers

- J18: DLPC350 HOLD_IN_BOOT. Jump across this header to hold the DLPC350 in bootloader mode. This is only needed if the DLP LightCrafter 4500 firmware becomes corrupted and needs to be reprogrammed through the JTAG boundary scan or USB. The graphical user interface (GUI) firmware upgrade process places the DLPC350 in bootloader mode through software commands and does not need the jumper.
- J19: device address select
  – Jump across header to set I2C address to 0x3A and USB device serial number to LCR3
  – Do not populate jumper to set I2C address to 0x34 and USB device serial number to LCR2
- J23: Hold in reset. Jump across header to drive and hold reset line low. Jumping across this header is equivalent to pressing and holding the reset switch.
- J28: DLPC350 LED signals voltage selection. This jumper needs to be populated when bypassing the on-board LED driver and using an external LED driver.
  – Jump across pins 1 to 2 to set the DLPC350 LED enables and PWM signals to 3.3 V
  – Jump across pins 3 to 4 to set the DLPC350 LED enables and PWM signals to 1.8 V
- J30: DLPC350 LED driver disable. This jumper needs to be populated when bypassing the on-board LED driver and using an external LED driver.
  – Jump across header to disable the on-board LED driver and turn off all LEDs, regardless of the DLP LightCrafter 4500 video mode
  – Do not populate this header for normal operation using the on-board LED driver

1.6 Dimensions

The DLP LightCrafter 4500 optical engine is mounted on top of a thermal plate to provide passive cooling to the module. The LEDs have a heat sink and fan to provide active cooling. The DLP4500, 0.45-in. DMD, is vertically mounted at the end of the optical engine and attached with a flex cable to the Driver Board that lies on top of the Light Engine. The DLP LightCrafter 4500 has dimensions of 98 mm long, 121.6 mm wide, and 47.7 mm tall. Figure 1-12 illustrates DLP LightCrafter 4500 dimensions.

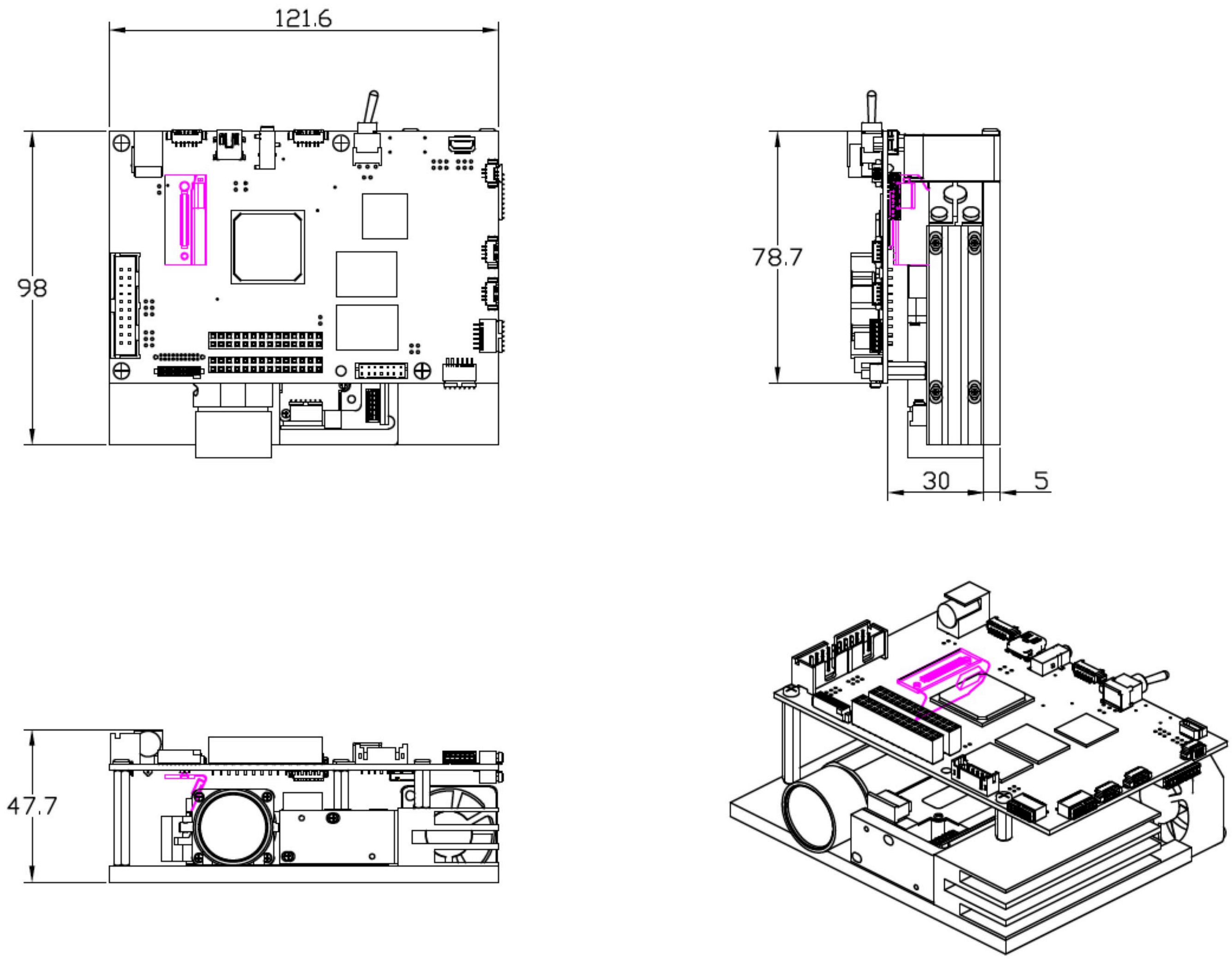


Figure 1-12. DLP LightCrafter 4500 Dimensions

Quick Start

This chapter details the steps to power up the DLP LightCrafter 4500 and connect to a PC.

2.1 Power-up the DLP LightCrafter 4500

The DLP LightCrafter 4500 is ready to use, out of the box. Steps 1 through 5 show how to power, display an image, and connect the device to a PC.

1. Connect a 12-V DC power supply to the power supply connector (connector 2 in Figure 1-8)
2. An LED on the bottom of the LightCrafter 4500 board, next to the flex cable lights up green. The fan starts, stops, and then restarts while the DLPC350 is booting. After 5 to 10 seconds, the DLPC350 bootloads and displays a screen with the DLP and LightCrafter 4500 logo. The D4 LED on top of the LightCrafter 4500 board flashes on and off green. If the board shuts down after briefly turning on the display, the power supply current rating might be too low.
3. To display video, connect a DVI source to the mini-HDMI connector (connector 20 in Figure 1-8)
4. Control the DLP LightCrafter 4500 with the free GUI software (available to download from http://www.ti.com/dlplightcrafter4500)
5. After installing the software on the computer, connect the PC to the DLP LightCrafter 4500 using a USB to mini-USB cable (connector 4 in Figure 1-8). The first time the cable is connected on a PC, the DLP LightCrafter 4500 enumerates as a USB composite device with human-interface device (HID) class. No drivers are required since these are natively handled by all operating systems.

Operating the DLP LightCrafter 4500

This chapter introduces the PC software provided with the DLP LightCrafter 4500.

3.1 DLP LightCrafter 4500 Software

The DLP LightCrafter 4500 includes a QT-based GUI application to control the module through the USB interface. QT is a Nokia cross-platform application and user-interface framework with open source and commercial licenses. To install the QT GUI, just expand the LightCrafter4500_GUI.zip file into a directory and double click on the executable file.

The DLP LightCrafter 4500 supports two main modes of operation:

- *Video Mode* displays images from:
  - DVI input through the mini-HDMI connector
  - 24-bit RGB bitmaps stored in flash memory
  - 24-bit, 20-bit, 16-bit, 10-bit, and 8-bit RGB input through the system board connectors (J1, J3, J4, and J6)
  - Internal test patterns
  - 30-bit RGB through flat panel display (FPD) link
- *Pattern Sequence* mode displays images from:
  - 1-, 2-, 3-, 4-, 5-, 6- ,7-, and 8-bit bitmap images stored in Flash memory
  - 1-, 2-, 3-, 4-, 5-, 6- , 7-, and 8-bit bitmap images streamed through the DLPC350 24-bit RGB interface (mini-HDMI, FPD-link, or system board connectors)

3.2 PC Software

Upon execution of the LightCrafter4500.exe, the window shown in Figure 3-1 displays. The GUI window contains the following two sections:

- The top portion of the GUI window displays the *System Status* and controls the *Operating Mode*, *Image Orientation*, *LED Driver Control* settings, and *LED Selection*. There are also controls for saving and applying solutions.
- The bottom portion of the GUI window offers a set of tabs to further control the selected *Operating Mode*.

In any of the GUI sections, clicking a **Get** button reads the current settings of that particular subsection. Clicking on the **Set** button programs the settings in the respective subsection. Please note that some commands may require additional steps before the GUI display is updated.

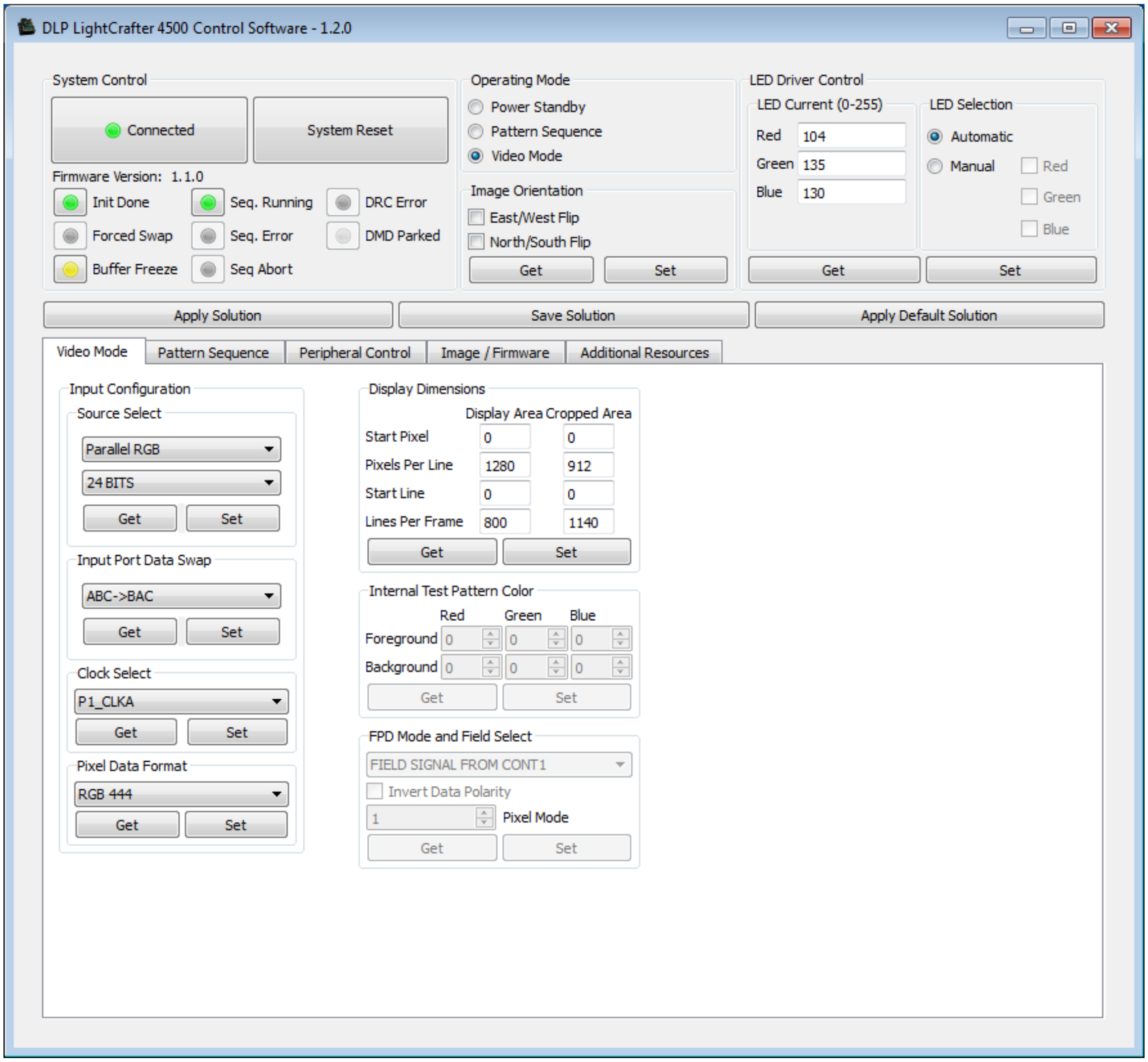


Figure 3-1. DLP LightCrafter 4500 GUI - Video Mode

The DLP LightCrafter 4500 GUI communicates with the DLPC350 using USB 1.1. The DLPC350 enumerates as a USB device with HID Support. The PC polls all the HID peripherals and once the PC detects the DLPC350, the **Connected** button changes color to green. If the USB cable is disconnected, the **Connected** button changes color to red and the *Connected* text is grayed-out. Once the *System Status* shows **Connected**, the firmware version, hardware, and *System Status* indicators are displayed. There is no need to press the **Connected** button, since the HID peripheral is detected by the operating system after USB enumeration.

3.2.1 System Status

At the top left portion of the GUI window, the hardware and *System Status* indicators report the following:

- Init Done: When highlighted green, it indicates the successful completion of the DLPC350 initialization. When highlighted grey, it indicates the DLPC350 had an error during its initialization procedure.
- Sequencer Running: When highlighted green, the DLPC350 sequencer is running as usual. When highlighted gray, the DLPC350 sequencer is stopped.
- DRC Error: DMD Reset Controller Error indicator. When highlighted grey, the DMD Reset Controller has not detected an error. When highlighted red, the DMD Reset Controller has found multiple overlapping bias or reset operations accessing the same DMD block of micromirrors.
- Forced Swap: When highlighted red, the DLPC350 sequencer detected a forced buffer swap error

indicating that image data has been displayed from the wrong internal display buffer. When highlighted grey, no buffer swap error has occurred. This error can occur if the DLP LightCrafter 4500 is set to *Video Mode* and the vertical backporch timing is too small. The error can also occur if the DLP LightCrafter 4500 is set to *Pattern Sequence* mode with patterns input from the video port and pattern sequence timings do not match the video port VSYNC.

- Sequencer Error: When highlighted red, the DLPC350 sequencer has detected an error. When highlighted gray, the DLPC350 sequencer detected that no error occurred.
- DMD Parked: When highlighted yellow, the DMD micromirrors are parked in the position normal to the DMD plane. When highlighted grey, the DMD micromirrors are not parked.
- Buffer Freeze: When highlighted yellow, the frame buffer is frozen. When highlighted gray, the frame buffer is not frozen. This is cleared on the next buffer swap.
- Sequencer Abort: When highlighted red, the DLPC350 sequencer has detected an error condition that caused an abort. When highlighted gray, the DLPC350 sequencer detected that no error occurred.

These indicators are updated every two seconds, or when a command is issued to the DLPC350.

3.2.2 Operating Mode

To the right of the *System Status*, the *Operating Mode* sets how the DLP LightCrafter 4500 operates:

- *Video Mode*: The DLPC350 takes 24-bit, 20-bit, 16-bit, 10-bit, and 8-bit data from one of the following interfaces:
  - 24-bit RGB interface
  - FPD-link interface
  - Internal test pattern generator
  - Flash memory

  The DLPC350 then applies video processing functions, such as scaling, gamma correction, and color coordinate adjustments, and sends the processed image to the DMD.
- *Pattern Sequence* mode: The DLPC350 takes 1-, 2-, 3-, 4-, 5-, 6-, 7-, and 8-bit data from one of the following interfaces:
  - 24-bit RGB interface
  - FPD-link interface
  - Flash memory

  The DLPC350 does not apply any video processing functions and provides a pixel accurate mode where every pixel maps to the native DMD resolution of 912 × 1140.
- *Power Standby*: Places the DLPC350 in low power state and powers down the DMD interface.

3.2.3 Image Orientation

Beneath the *Operating Mode*, the *Image Orientation* controls the long and short axis flips to support front, rear, table, and ceiling mounted projection. The *Image Orientation* takes place on the next image or frame load in *Video Mode*, and on the next download to the DLP LightCrafter 4500 in *Pattern Sequence* mode.

- *East and West Flip*: If checked, the image is flipped along the east and west axis of the projected image. Usual table front projection has this setting unchecked. Otherwise, the image is flipped horizontally.
- *North and South Flip*: If checked, the image is flipped along the north and south axis of the projected image. Usual table front projection has this setting unchecked. Otherwise, the image is flipped vertically.

3.2.4 LED Current Settings

On the top right of the GUI window, the *LED Current* settings control the individual currents of the red, green, and blue LEDs. A setting of 255 corresponds to the maximum LED current. A setting of 0 corresponds to minimum LED current. The LED current is computed as follows:

$$\text{Red LED Current (A)} = 0.0175 \times (\text{LED Current Value}) + 0.4495 \tag{1}$$

$$\text{Green LED Current (A)} = 0.0181 \times (\text{LED Current Value}) + 0.3587 \tag{2}$$

$$\text{Blue LED Current (A)} = 0.0160 \times (\text{LED Current Value}) + 0.1529 \tag{3}$$

Typical performance of the red, green, and blue LEDs are shown in Figure 3-2, Figure 3-3, and Figure 3-4, respectively. Note that manufacturing processes can lead to variations in LED brightness and current consumption. Actual LED performance might vary from those illustrated in the following figures.

CURRENT AND ILLUMINANCE
vs
PWM VALUE

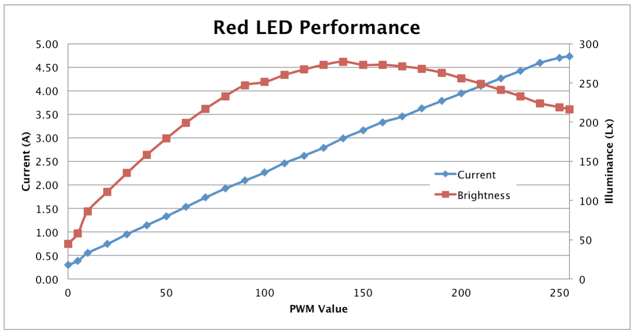


Figure 3-2. Typical Red LED Current and Illuminance Based on PWM values

CURRENT AND ILLUMINANCE
vs
PWM VALUE

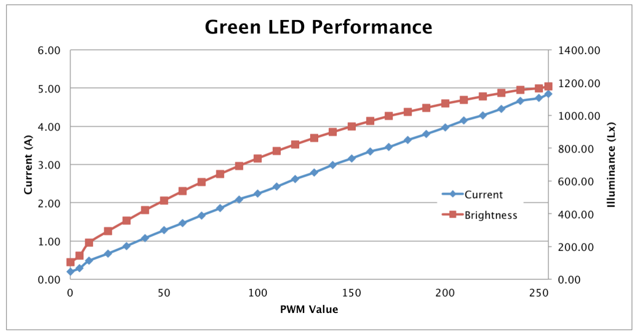


Figure 3-3. Typical Green LED Current and Illuminance Based on PWM values

CURRENT AND ILLUMINANCE
vs
PWM VALUE

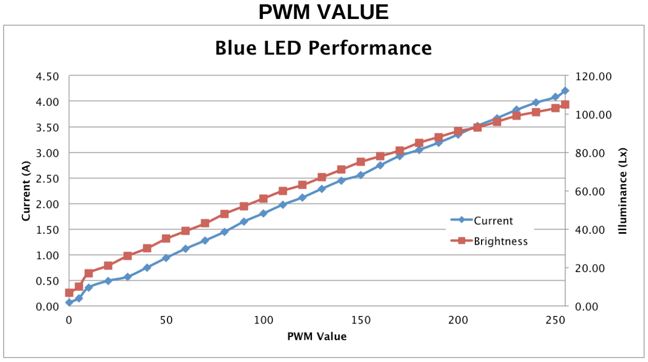


Figure 3-4. Typical Blue LED Current and Illuminance Based on PWM values

CAUTION

The DLP LightCrafter 4500 is an actively cooled system that has a thermal limit resulting in total simultaneous red, green, and blue LED currents less than 4.3 A for continuous LED operation. Do not overheat the system by turning all LEDs at maximum power during prolonged and simultaneous LED use. Exceeding more than 4.3 A for continuous or simultaneous LED operation can damage the LightCrafter 4500 LEDs.

Typical variations in LED manufacturing can lead to changes in the brightness and current consumption. Thus for typical white balance point, TI recommends the following percentages of colors:

- Red or green is approximately 87.5%
- Blue or green is approximately 97.6%

At the default LED current values of:

- Red = 104
- Green = 135
- Blue = 130

The *LED Selection* box determines the control of the LED enables signals. Two options are allowed:

- *Automatic*: LED enables are controlled by the DLPC350 sequencer. In *Video Mode*, the LED enables are color sequentially set. In *Pattern Sequence* mode, the LED enables are controlled by the downloaded *Pattern Sequence* settings.
- *Manual*: LED enables are controlled by the check boxes. Checking a color, continuously enables the LED of that color at the given LED current setting.

3.2.5 Video Mode

When the DLP LightCrafter 4500 is configured in *Video Mode*, the *Input Source Select* section in the top left part of the *Video Mode* tab selects the input source to be displayed by the DLPC350. The DLPC350 treats these as video inputs and applies image processing functions, like scaling, gamma correction, and color coordinate adjustments, and so forth. The following lists the allowable input sources:

- Parallel RGB interface: Supports 24-, 20-, 16-, 10-, and 8-bit data inputs. This interface is connected to the TFP401 for DVI input from the mini-HDMI connector or to the system board connectors. The Pixel Data Format section to the right of the Source Select interface selects the allowable pixel data formats for the Parallel RGB interface:
  - RGB 4:4:4
  - YCrCb 4:4:4
  - YCrCb 4:2:2
- Internal Test Pattern: 24-bit internal pattern generator with RGB 4:4:4 pixel data format. The internal test patterns offer color control of the foreground and background color of the pattern through the *Internal Test Pattern Color* section. The available internal test patterns and their respective foreground and background color control are:
  - Solid field: Foreground color control only
  - Horizontal ramp: Foreground color control only
  - Vertical ramp: Foreground color control only
  - Horizontal lines: Foreground and Background color control
  - Diagonal lines: Foreground and Background color control
  - Vertical lines: Foreground and Background color control
  - Grid: Foreground and Background color control
  - Checkerboard: Foreground and Background color control
  - Red, green, and blue ramps: Foreground color control only
  - Color bar: Foreground color control only
  - Step bar: Foreground color control only
- Flash images: single-frame, 24-bit still images stored in external Flash memory. The Flash memory supports up to 32MB of storage with up to 64 images. The images stored in flash memory support RGB 4:4:4 and YCrCb 4:2:2 pixel data formats.
- FPD-link: Flat Panel Display Link connector. The FPD-link interface supports 30-, 24-, 20-, 16-, 10-, and 8-bit data inputs with RGB 4:4:4 pixel data format. The *FPD Mode and Field Select* configures the mapping of the pixel mode, polarity, and CONT1 and CONT2 field signals.

For the Parallel RGB and FPD-link video input modes, the DLPC350 interprets channel A as green, channel B as red, and channel C as blue. However, the Parallel RGB or FPD-link source can have different mapping of channels to colors. The *Input Source Port Data Swap* section sets the mapping of channels to colors. Port1 refers to Parallel RGB interface while Port2 refers to the FPD-link interface. The mapping options are:

- ABC → ABC, no swapping of data sub-channels
- ABC → CAB, data sub-channels are right shifted and circularly rotated
- ABC → BCA, data sub-channels are left shifted and circularly rotated
- ABC → ACB, data sub-channels B and C are swapped
- ABC → BAC, data sub-channels A and B are swapped
- ABC → CBA, data sub-channels A and C are swapped

For all video input modes, the *Display Dimensions* section defines the active displayed resolution. The maximum supported input and output resolutions for the DLP4500 0.45 WXGA DMD are 1280 pixels (columns) by 800 lines (rows). The display area settings set the first pixel column (*Start Pixel*) and the first line (*Start Line*), as well as, the numbers of pixels per line (total columns) and the number of lines per frame (total rows). This setting also provides the option to define a subset of active input frame data using pixel (column) and line (row) counts. In other words, this feature allows the source image to be cropped as the first step in the processing chain.

3.3 Pattern Sequence Mode

When the DLP LightCrafter 4500 is configured in *Pattern Sequence* mode, the DLPC350 supports 1-, 2-, 3-, 4-, 5-, 6-, 7-, and 8-bit images with a 912 columns by 1140 rows resolution. These images are pixel accurate, meaning that each pixel corresponds to a micromirror on the DMD and is not processed by any of the video processing functions. There are three sub-tabs for controlling the *Pattern Sequence* settings: *Sequence Settings*, *Trigger Controls*, and *LED Delay Control*.

3.3.1 Sequence Settings

A pattern sequence is composed of several patterns loaded from flash memory or streamed through the 24-bit RGB video port. Each individual pattern can have a specific set of LEDs illuminating it, a particular bit-depth, and an internal or external trigger. The *Sequence Settings* sub-tab allows the user to define and set all the *Individual Pattern Settings*. The *Trigger Controls* sub-tab and the *LED Delay Control* sub-tab set the trigger and LED enable edge timings. Figure 3-5 depicts the DLP LightCrafter 4500 GUI with the *Pattern Sequence* tab selected.

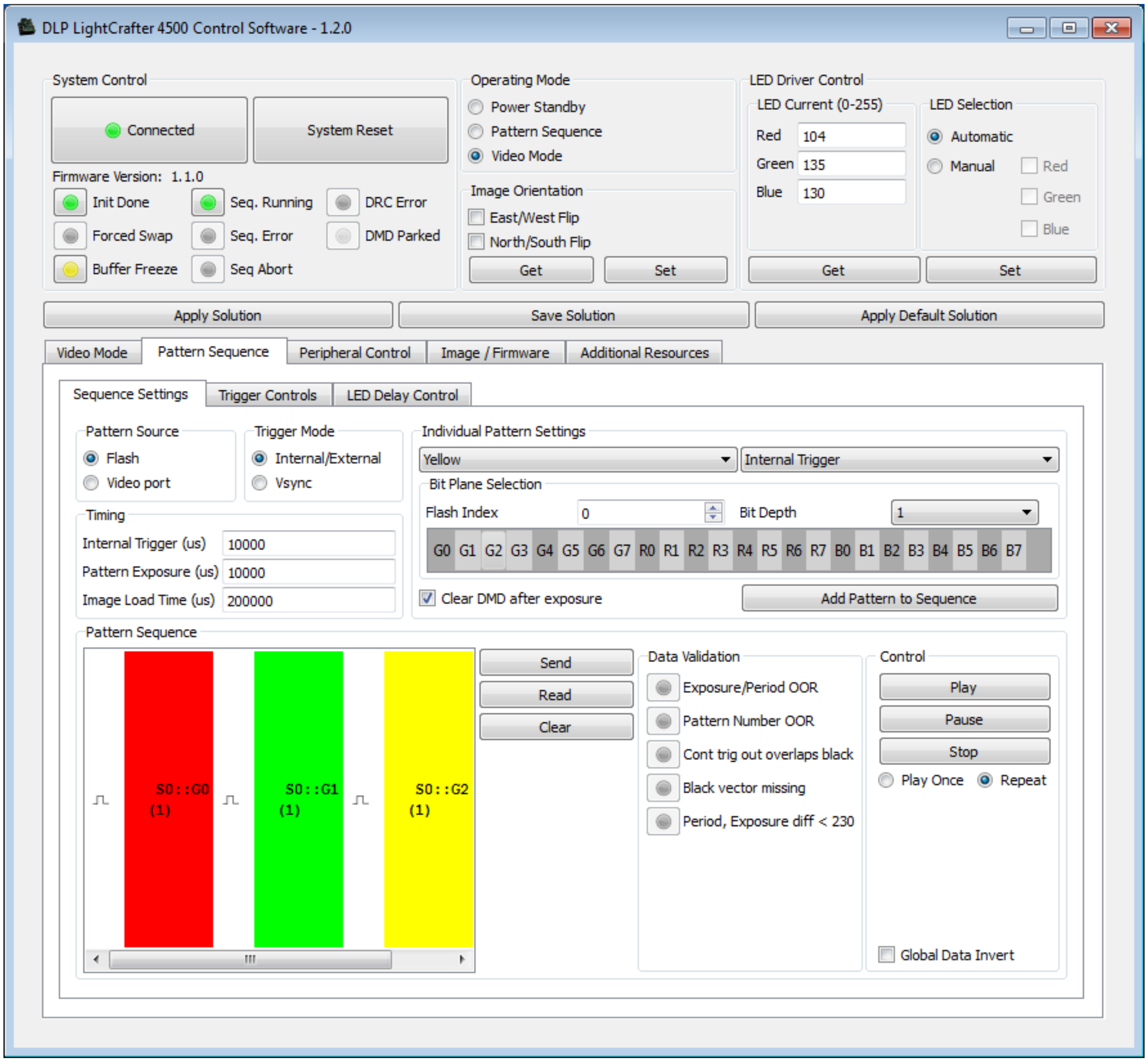


Figure 3-5. DLP LightCrafter 4500 GUI - Pattern Sequence Mode

The *Pattern Sequence* displays images from one of the following two input sources:

- *Flash*: Images stored in flash memory. The flash memory can store up to 64 24-bit compressed images.
- *Video port*: Streamed through the Parallel RGB or FPD-link interface. Only one of these interfaces can be connected to the DLP LightCrafter 4500 during *Pattern Sequence* mode.

To synchronize a camera or external system with the displayed patterns, the DLP LightCrafter 4500 supports a set of trigger inputs and outputs. These are configured through the *Trigger Mode* section and *Trigger Controls* sub-tab. The *Trigger Mode* selects the trigger input:

- *Internal/External*: Uses an internal trigger period to start the pattern sequence or uses the DLP LightCrafter 4500 TRIG_IN2 signal to start and pause the pattern sequence. Each pattern in the pattern sequence can be configured with either an internal or external trigger. With *Internal Trigger* setting, the Internal Trigger Period displays the next pattern. With External Trigger Period, the DLP LighCtrafter4500 TRIG_IN_1 signal displays the next pattern.
- *Vsync*: Utilizes the VSYNC signal from the Parallel RGB or FPD-link interface to trigger the start of the pattern sequence. After VSYNC, the patterns are displayed in the sequence shown on the *Pattern Sequence* section. Each pattern is determined by the Pattern Exposure time. Thus, the total number of patterns multiplied by the pattern exposure needs to be less than or equal to the VSYNC period.

Pattern sequence timing is controlled by the Internal Trigger period and Pattern Exposure period. Depending on the setting of the *Pattern Source* section, the bottom field will toggle from Image Load Time and Vsync period if the *Pattern Source* is set to flash images or video port, respectively.

- Internal Trigger period: Defines the amount of time between patterns (in microseconds) in a pattern sequence.
- Pattern Exposure period: Defines the amount of time a single pattern is displayed in microseconds.
- Vsync period: Only applicable when *Pattern Source → Video port* is selected. This field defines the amount of time between VSYNC pulses in microseconds. This field is used to validate the data programmed to the DLP LightCrafter 4500 and must match the VSYNC period of the Video interface (Parallel RGB or FPD-link).
- Image Load Time: The time it takes to load 24-bit fields of an image from external flash memory. Typical time is 200 ms. Once an image is loaded from flash, 24 bit-fields reside in the frame buffer and can be sequenced at higher speeds. Two 24 bit-field display buffers are available in the DLPC350. If the pattern sequence uses more than two images (48 bit-fields), then approximately 200 ms is required to load the new image into the DLPC350 internal display buffer.

A pattern sequence can be any combination of bit depth patterns with any combination of LED sources. The pattern sequence can be played once or continuously repeated. The allowed LED sources are:

- White: Red, green, and blue LEDs on
- Cyan: Green and blue LEDs on
- Magenta: Red and blue LEDs on
- Yellow: Red and green LEDs on
- Red: Only red LED on
- Green: Only green LED on
- Blue: Only blue LED on

To create a pattern sequence, follow these steps:

1. Choose pattern input source (flash or video port) from the *Pattern Source* section.
2. Choose internal or external, or VSYNC trigger mode from the *Pattern Trigger Mode* section.
3. Set the appropriate *Trigger Controls*
4. Set the *Internal Trigger* period, Pattern Exposure period, and Image Load Time or Vsync Time.
5. If the patterns sequence must be played once, set Play Once. This setting will play the number of patterns set in *Trigger Controls* sub-tab under "Trigger 2 Patterns per pulse". If set to 1, it plays the first pattern in the sequence and stops. If set to 10, it plays the first 10 patterns in the sequence. If the pattern sequence is to continuously repeat, set repeat. Make sure to click the **Send** button after clicking on *Play Once* to download the new settings.
6. Create the pattern sequence:
   (a) Choose the flash Image Index (if input from Splash Image) or Frame index (if input is from video port) and set the Bit depth on the *Individual Pattern Settings*. Then select the desired bit-plane to be displayed. The bit-planes are labeled G0-G7, R0-R7, and B0-B7. Clicking on these squares will select this bit-plane.
   (b) Choose the LEDs to illuminate this bit-plane
   (c) Select the trigger for the pattern: no trigger, external positive, external negative, or internal trigger. Note that creating an internally triggered pattern sequence with an external trigger input may cause unexpected behavior.
   (d) If a black image is desired between patterns, check the Clear DMD after exposure.
   (e) Click on **Add Pattern to Sequence** button
   (f) Repeat steps to for each pattern in the sequence
7. Click Send to LightCrafter. This executes a data validation and provides results in the Data Validation status section and informs the user if any of the trigger period or exposure are invalid. After successful data validation, the pattern sequence is downloaded to the DLP LightCrafter 4500 and started.

If there is a data validation problem, the appropriate status indicators are highlighted in the Data Validation section:

- *Exposure or Period OOR*: When highlighted red, the Pattern Exposure period or Frame period is out of range. The pattern exposure period must be greater than the fastest period supported, as shown in Table 4-1.
- *Pattern Number OOR*: When highlighted red, the Pattern Number is out of range. The maximum allowed patterns depend on the bit width and are listed in Table 4-1.
- *Cont trig out overlaps black*: When highlighted red, the continuous pattern exposure has a trigger Out1 request or overlapping black sectors.
- *Black vector missing*: When highlighted red, the black vector is missing.
- *Period, Exposure diff < 230*: When highlighted red, the difference between the frame period or internal trigger period and the exposure period of a pattern is less than 230 µs. The DMD needs 230 µs for loading a pattern, so the trigger or frame period must be 230 µs greater than the pattern exposure time.

Pause or restart the pattern sequence through the **Play** and **Pause** buttons, respectively. If a pattern sequence was previously loaded, the user can click on **Read** to load it into the GUI window.

The *Pattern Sequence* section illustrates the pattern sequence as a set of colored rectangles. The color corresponds to the LEDs used. The entries on the rectangles represent the image source, the bit-plane, and the bit-depth as follows: S0::G0 (1) indicates Flash location 0, bit-plane = G0, bit-depth = 1. F2::G5 (3) indicates Frame #2, bit-plane = G5, bit-depth = 3. For example, in Figure 3-5, a pattern sequence of three patterns is displayed. Each pattern is triggered every 100 ms and exposed for 100 ms. The first pattern is a 1-bit green pattern using bit-plane G0 from Flash location 0. The second pattern is a 1-bit blue pattern using bit-plane G1 from Flash location 0. The third pattern is a 1-bit red pattern using bit-plane G2 from Flash location 0.

A pulse icon in between the patterns indicates that a trigger is needed between the patterns. Right-clicking on this icon allows the removal of the trigger, so two or more patterns can share the same trigger and are exposed in sequence for the total exposure time. Right-clicking on a pattern allows the option of inverting the pattern, removing the pattern, or inserting a black image by clearing the DMD after exposure time.

3.3.1.1 Pattern Sequence Example

To illustrate the *Pattern Sequence* mode, this section describes the steps to create a Gray Code sequence with Green LED. The DLPC350 Firmware has several sets of images stored in the flash memory. Flash Image 8 corresponds to 24 1-bit gray code images that have been packed into a single 24-bit RGB bitmap. To load the pattern sequence, perform the following steps:

- Select *Pattern Source*: Flash
- Select Pattern Trigger Mode: Internal or External
- Set Timing of Internal Trigger: 100000 µs
- Set Pattern Exposure: 100000 µs
- Set Image Load Time: 200000 µs
- From the *Individual Pattern Settings*: Select *Green* and *Internal Trigger*
- Flash Image: Select 8
- For each of the 24 bit-planes of the packed 24-bit RGB image, select one bit-plane (a monochrome image) and add it to the pattern sequence by:
  - Clicking on G0, then clicking on **Add Pattern to Sequence** button
  - Clicking on G1, then clicking on **Add Pattern to Sequence** button
  - Clicking on G2, then clicking on **Add Pattern to Sequence** button
  - Clicking on G3, then clicking on **Add Pattern to Sequence** button
  - Clicking on G4, then clicking on **Add Pattern to Sequence** button
  - Clicking on G5, then clicking on **Add Pattern to Sequence** button
  - Clicking on G6, then clicking on **Add Pattern to Sequence** button
  - Clicking on G7, then clicking on **Add Pattern to Sequence** button
  - Clicking on R0, then clicking on **Add Pattern to Sequence** button

- Clicking on R1, then clicking on **Add Pattern to Sequence** button
- Clicking on R2, then clicking on **Add Pattern to Sequence** button
- Clicking on R3, then clicking on **Add Pattern to Sequence** button
- Clicking on R4, then clicking on **Add Pattern to Sequence** button
- Clicking on R5, then clicking on **Add Pattern to Sequence** button
- Clicking on R6, then clicking on **Add Pattern to Sequence** button
- Clicking on R6, then clicking on **Add Pattern to Sequence** button
- Clicking on R7, then clicking on **Add Pattern to Sequence** button
- Clicking on B0, then clicking on **Add Pattern to Sequence** button
- Clicking on B1, then clicking on **Add Pattern to Sequence** button
- Clicking on B2, then clicking on **Add Pattern to Sequence** button
- Clicking on B3, then clicking on **Add Pattern to Sequence** button
- Clicking on B4, then clicking on **Add Pattern to Sequence** button
- Clicking on B5, then clicking on **Add Pattern to Sequence** button
- Clicking on B6, then clicking on **Add Pattern to Sequence** button
- Clicking on B7, then clicking on **Add Pattern to Sequence** button

• This forms 24 1-bit images that are displayed back-to-back at 100-ms exposure. Click on the **Send** button to download the pattern sequence to the LightCrafter 4500.

3.3.2 Trigger Controls

The *Trigger Controls* sub-tab sets the polarity and adjusts the rising and falling edge delay of the trigger inputs and outputs. The following trigger controls are available:

• TRIG_IN_1:
  - Trigger 1 In Delay: Sets the rising edge delay of the DLPC350 TRIG_IN_1 signal in relation to the display of the pattern on the DMD. Each number adds 107.136 ns. Range is –20.05 µs (before pattern exposure) to +7.29 µs (after pattern exposure) delay.

• TRIG_OUT_1:
  - Trigger 1 Out Rising Edge Delay: Sets the rising edge delay of the DLPC350 TRIG_OUT_1 signal in relation to the display of the pattern on the DMD. Each number adds 107.136 ns. Range is –20.05 µs (before pattern exposure) to +2.79 µs (after pattern exposure) delay.
  - Trigger 1 Out Falling Edge Delay: Sets the falling edge delay of the DLPC350 TRIG_IN_1 signal in relation to the display of the pattern on the DMD. Each number adds 107.136 ns. Range is –20.05 µs (before pattern exposure) to +2.79 µs (after pattern exposure) delay.
  - Invert Trigger 1 Out: Sets the polarity of the TRIG_OUT_1 signal. When unchecked, the polarity of TRIG_OUT_1 is active high. When checked, the polarity of TRIG_OUT_1 is active low.

• TRIG_OUT_2:
  - Trigger 2 Out Rising Edge Delay: Sets the rising edge delay of the DLPC350 TRIG_OUT_2 signal in relation to the display of the pattern on the DMD. Each number adds 107.136 ns. Range is –20.05 µs (before pattern exposure) to +7.29 µs (after pattern exposure) delay.
  - Invert Trigger 2 Out: Sets the polarity of the TRIG_OUT_2 signal. When unchecked, the polarity of TRIG_OUT_2 is active high. When checked, the polarity of TRIG_OUT_2 is active low.
  - Patterns per Trigger Out 2: Indicates the number of patterns per TRIG_OUT_2 pulse.

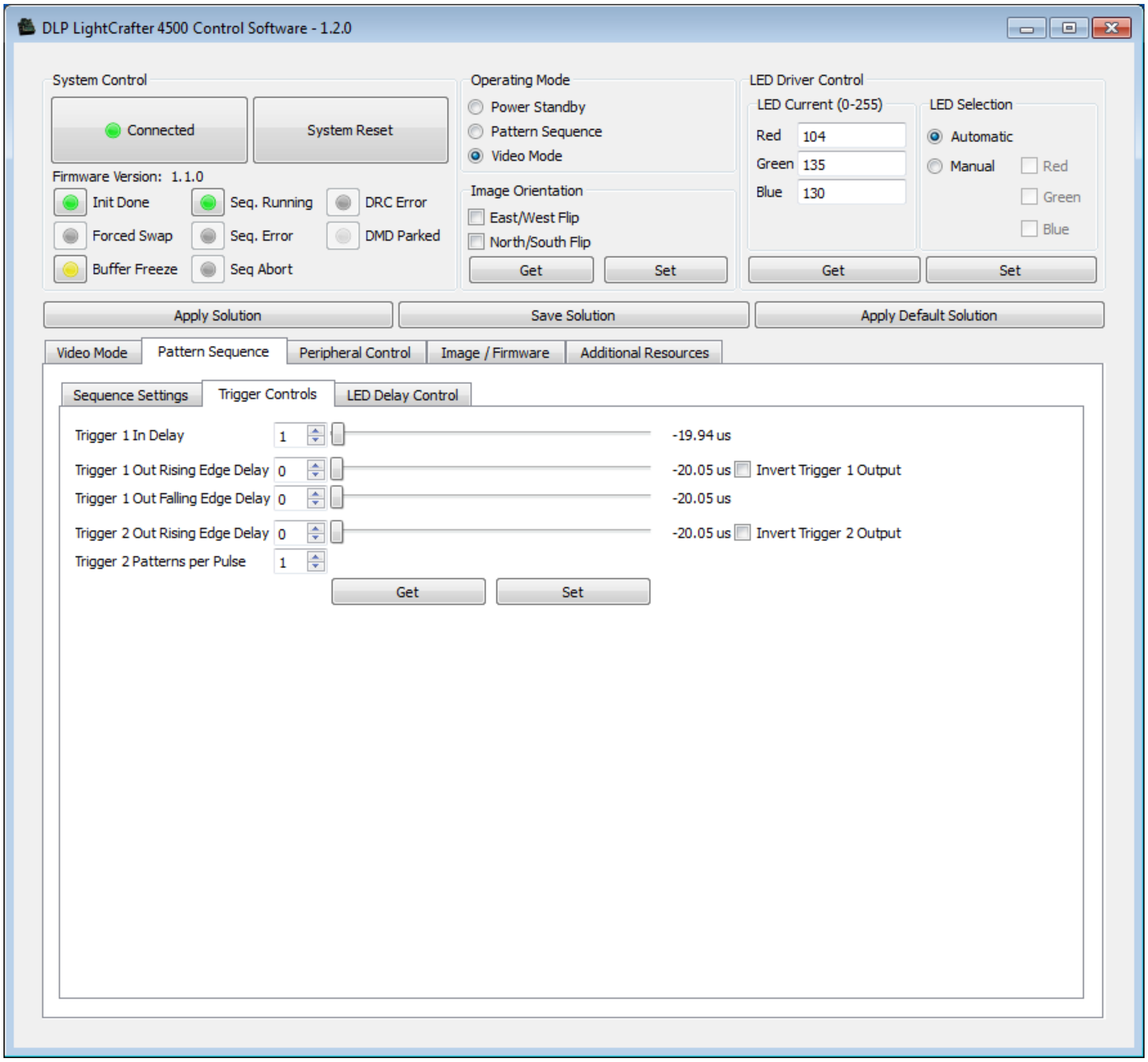


Figure 3-6. Trigger Control Sub-tab

The trigger output signals are:

- TRIG_OUT_1 frames the exposure time of the pattern
- TRIG_OUT_2 indicates the start of the pattern sequence or internal buffer boundary of a 24-bit-plane.

Examples of signals are depicted in Figure 3-7 and Figure 3-8

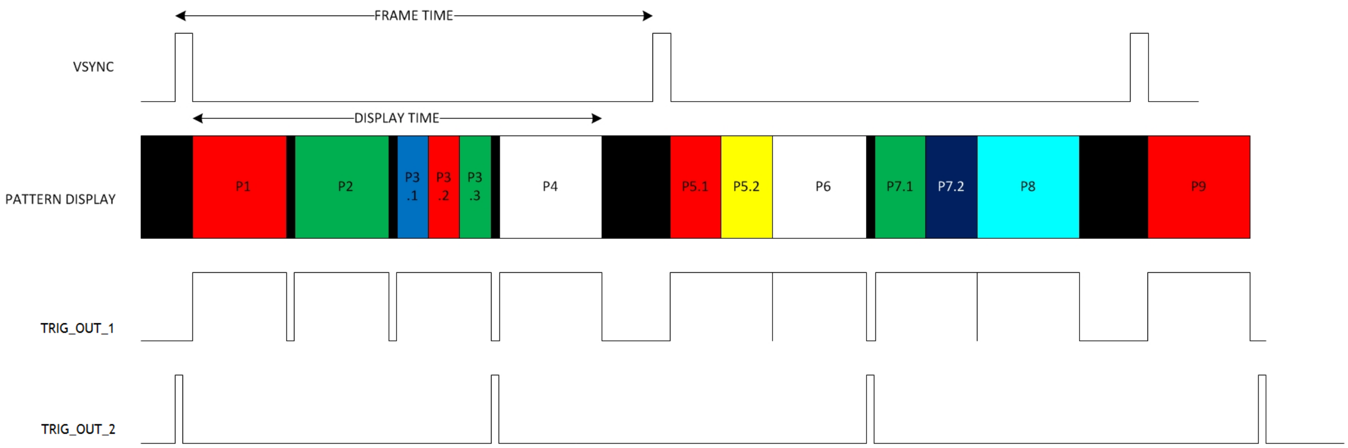


Figure 3-7. VSYNC Pattern Trigger Mode

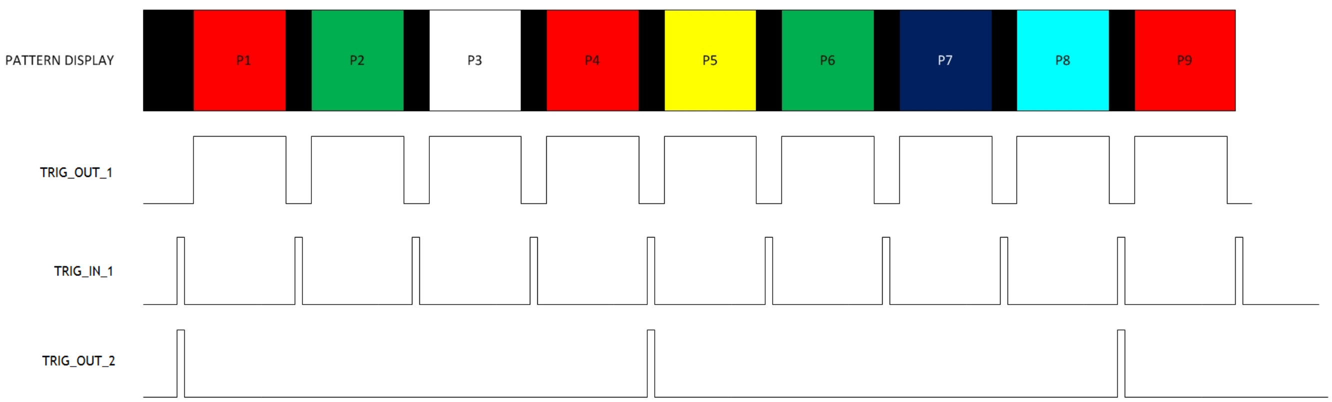


Figure 3-8. External Pattern Trigger Mode

3.3.3 LED Delay Control

In *Pattern Sequence* mode, the *LED Delay Control* sub-tab sets the rising and falling edge offsets of the LED enable signals in relation to the display of the pattern on the DMD. The rising and falling edge of the red, green, and blue LED enable signals can be independently changed between –20.05 µs (before pattern exposure) to +7.29 µs (after pattern exposure) delay.

When the DLP LightCrafter 4500 is operating in *Video Mode*, set these delays to 0 (–20.05 µs).

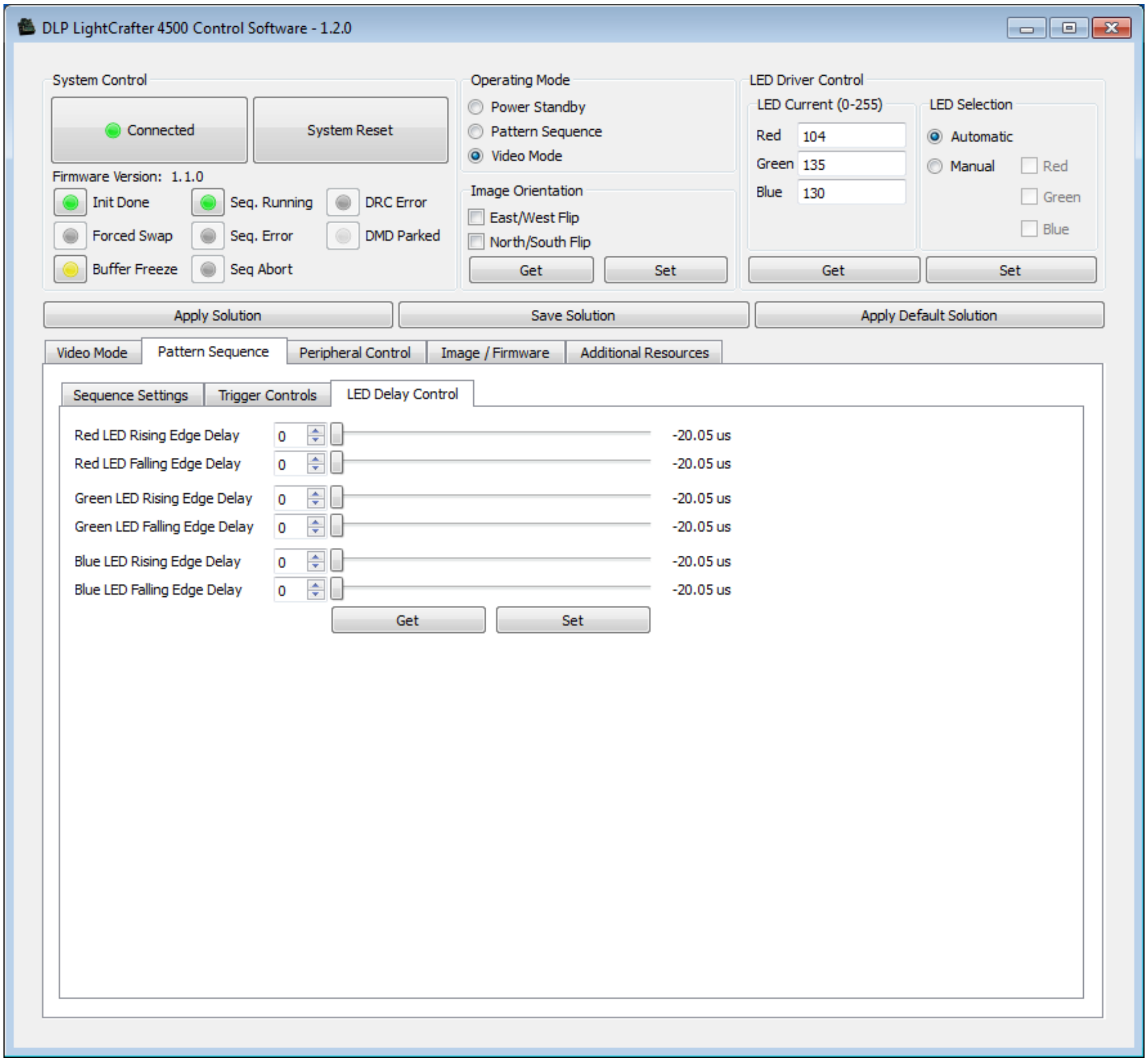


Figure 3-9. LED Delay Control Sub-tab

3.4 Firmware Upgrade

The DLP LightCrafter 4500 GUI allows field updates of the DLPC350 firmware. To update the DLPC350 firmware, perform the following steps:

1. Select the *Image / Firmware* tab and the *Firmware Upload* sub-tab shown in Figure 3-10
2. Click the *Browse* button to select the file to install
3. Click on **Upload** button
4. Wait for the upload process to complete. The flash memory is erased first, then re-written with the new firmware image selected.

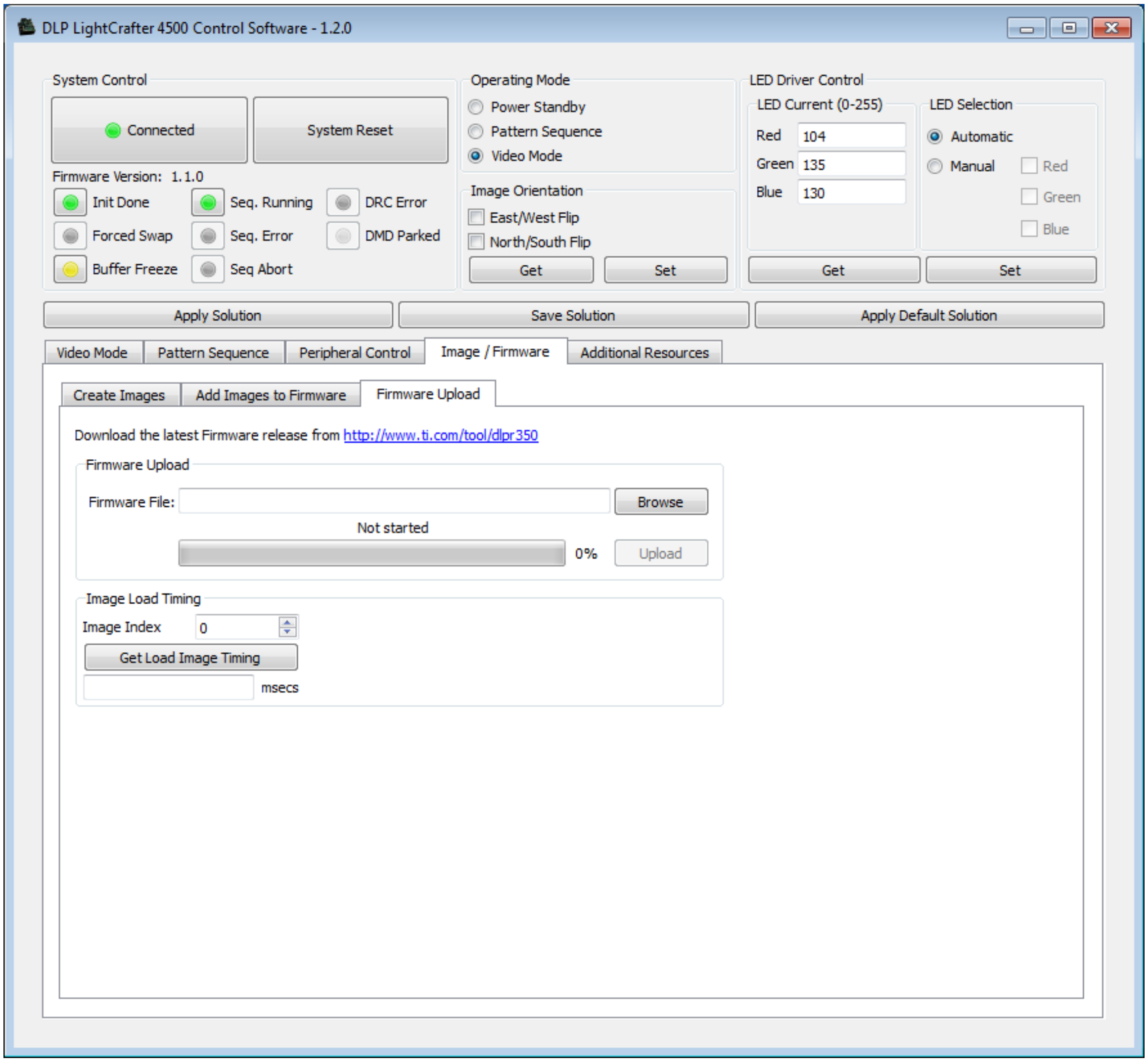


Figure 3-10. Firmware Upgrade Tab

3.5 Image Load Timing

The bottom section of the *Firmware Upload* contains Image Load Timing. This section does an instant calculation on the time the DLPC350 takes to load a full 24-bit RGB bitmap from flash. This measurement is instantaneous and is not the average nor worst case timing. To get an instantaneous measurement, perform the following steps:

- Select the desired image number from the "Image Index".
- Select the **Get Load Image Timing** button.

The DLPC350 decompresses the 24-bit RGB bitmap stored at the Image Index location and loads it to the internal buffer. The time required for this process is displayed in milliseconds. Note that this feature overwrites the images currently in the display buffer.

3.6 Storing Images in Flash Memory

LightCrafter 4500 allows images to be compressed and stored into the 32MB flash memory. For most efficient storage and compression of images, stored images are packed into groups of 24-bit RGB bitmap images and decompressed on the fly while loaded from flash memory. To ease the packing of any bit width images, the LightCrafter 4500 GUI offers the Create Images sub-tab. To create a 24-bit image from different multiple bit depth images, perform the following steps:

1. Select the *Image / Firmware* tab and the *Create Images* sub-tab.
2. Select a bitmap file with 912 columns by 1140 rows by clicking the **...** button next to *Input bmp file*
3. Select Output bitmap file by clicking the **...** button next to the *Output bmp file*
4. For an input file, add the individual bit-planes by repeating the following process:
   (a) Set the bit depth and the bit field position with the *Bit depth* and the *At bit position* pulldown selectors
   (b) Click on the **Add to Output File** button. The current image is bit weighted and saved into the 24-bit image of the output file.

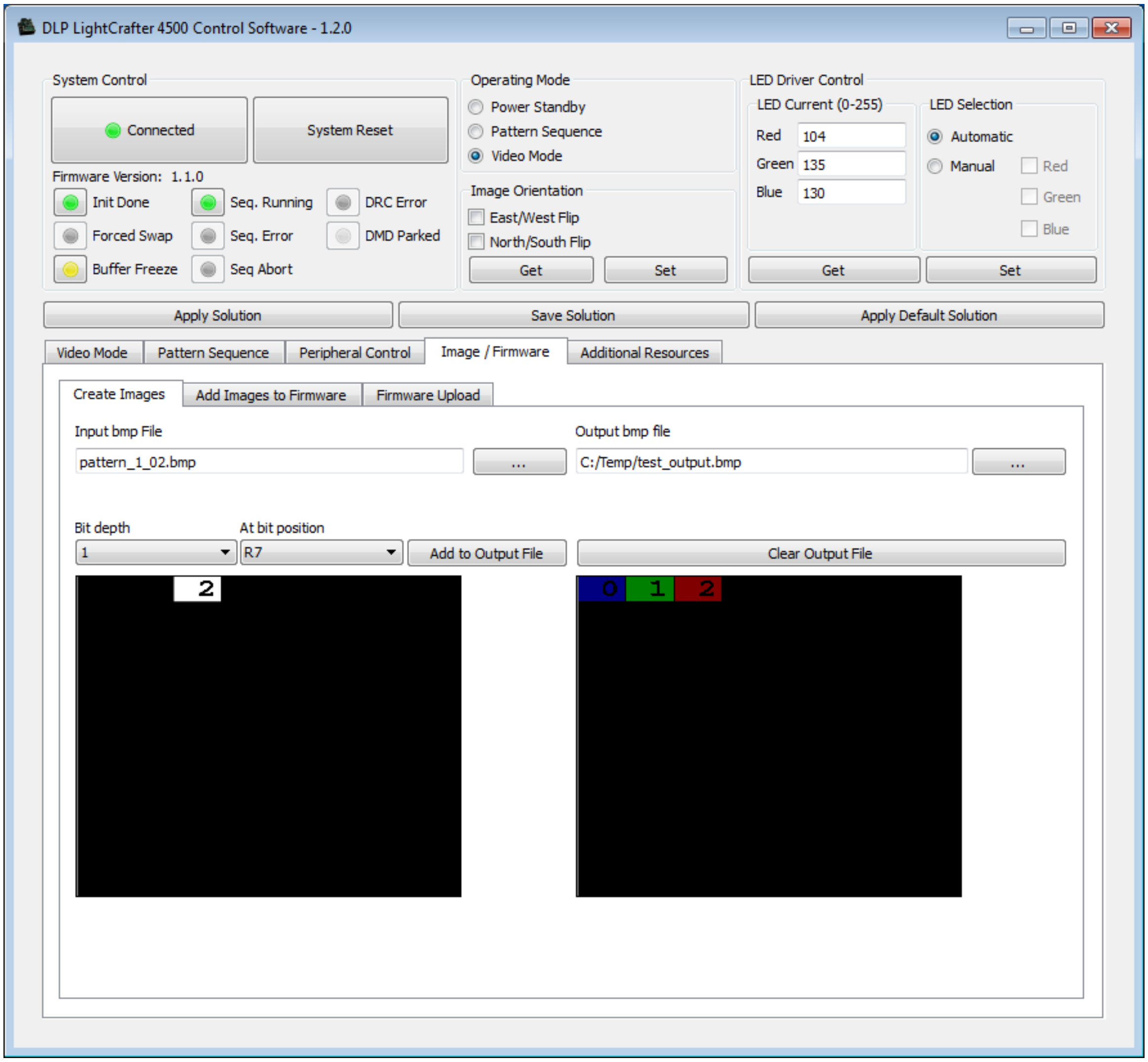


Figure 3-11. Create Images Tab

Underneath these selections, the left hand window shows a preview of the Input file. The right hand window shows a preview of the 24-bit output file that has taken all the input files and bit weighted the added images according to the bit-plane position requested. Note that images added at bit position B0 to B7 show blue, bit position G0 to G7 show green, and bit position R0 to R7 show red. For each color, bit position 0 is the least significant bit, while bit position 7 is the most significant bit.

To download the images into flash, a series of 24-bit images must be added to the firmware file using the "Add Images to Firmware" sub-tab with the following steps:

1. Select the *Image / Firmware* tab and the *Add Images to Firmware* sub-tab.
2. Select a firmware file by clicking the **Browse** button next to "Firmware File."
3. Add several 24-bit images by:
   (a) Selecting the location of the image using the pull down, and clicking on the **Add** button. Browse the 24-bit image file created in the Create Images tab, and select it. The image is displayed next to these buttons.
4. If a new .ini file is desired, refer to Section 5.2. Otherwise, after adding all the images to the firmware, click on **Save Updates** button.
5. Download the firmware to the LightCrafter 4500 by following the steps for the Firmware Upgrade found in Section 3.4.

After clicking on "Build firmware", all the 24-bit images are compressed and packed together. The number of the image might differ from the one in the pulldown due to the packing of the 24-bit images.

3.7 GPIO Control

DLPC350 offers several configurable pins. The Peripheral Control tab of the GUI controls how these pins are configured. The following options are available:

- General Purpose Clock: Two DLPC350 pins can be individually configured as clocks.
- PWM Output: Two DLPC350 pins, GPIO_00 (pin 18 in J6) and GPIO_02 (pin 22 in J6), can be individually set as PWM outputs.
- GPIO Configuration: Several DLPC350 pins can be individually configured as GPIO. Once configured as GPIO, the pin direction (input or output), if set to output the pin state (high or low) and output type (open drain output or drive high or low) can be configured. Some GPIO pins are already configured by the firmware for specific functions and these are listed with their current configuration.
- PWM Capture: Two DLPC350 pins, GPIO_05 (pin 14 in J6) and GPIO_06 (pin 17 in J6), can be individually set as PWM inputs. These pins will sample at the frequency specified in "PWM Sample Rate" and report the duty cycle of the input signal.

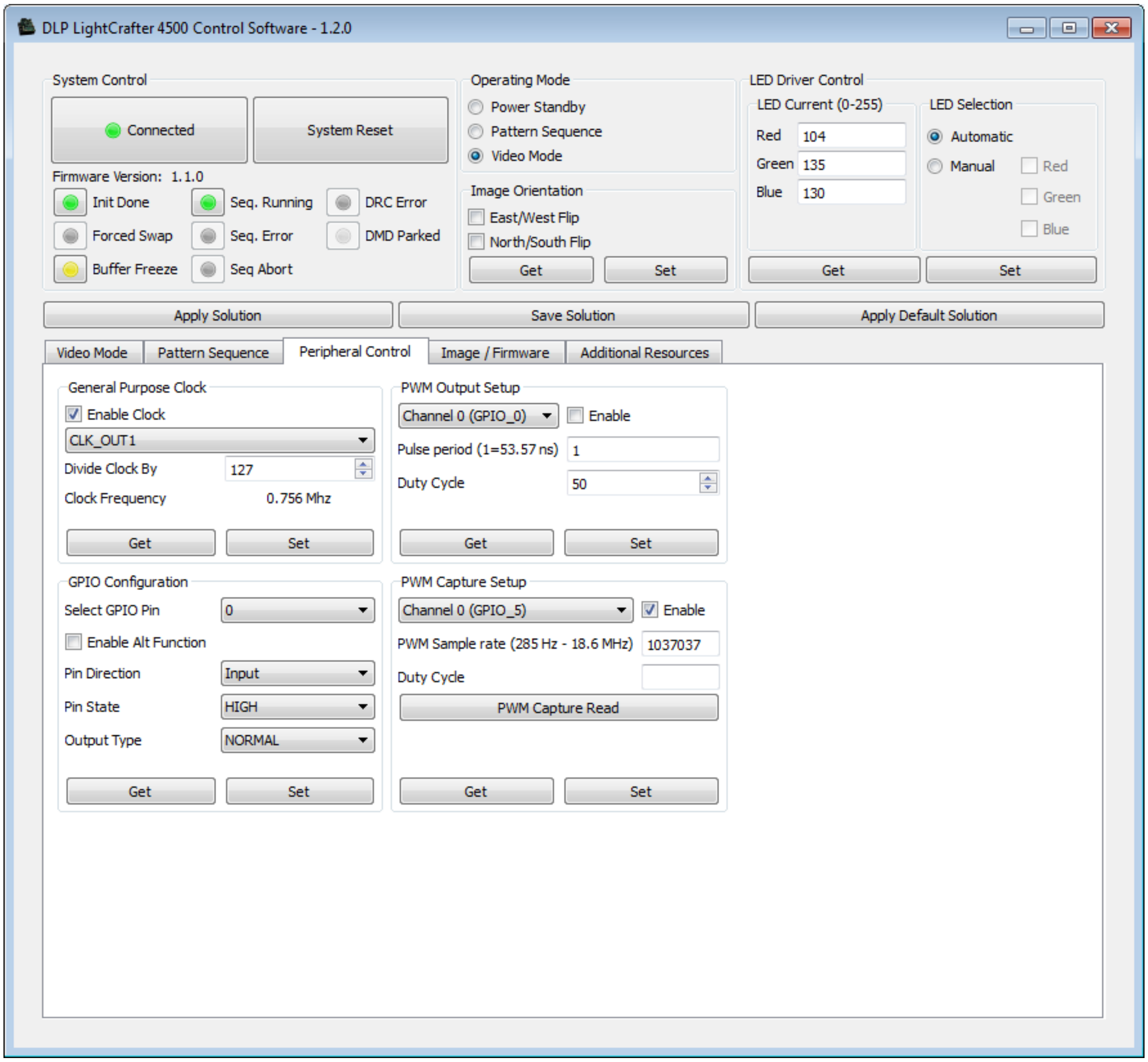


Figure 3-12. Peripheral Control Tab

Pattern Sequences

This chapter describes the pattern sequences supported by the DLP LightCrafter 4500 Module.

4.1 Pattern Sequence Background

The DLPC350 takes as input 24-, 27-, or 30-bit RGB data at up to 120-Hz frame rate. This frame rate is composed of three colors (red, green, and blue) with each color equally divided in the 120-Hz frame rate. Thus, each color has a 2.78-ms time slot allocated. Because each color has 8-, 9-, or 10-bit depth, each color time slot is further divided into bit-planes. A bit-plane is just a one-bit representation of all the pixels in the image. For example, a 24-bit image is decomposed into its bit-planes in Figure 4-1.

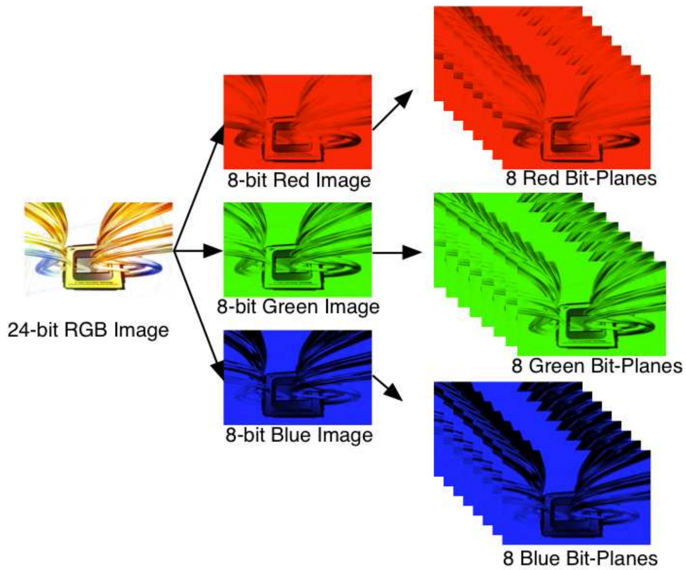


Figure 4-1. Relationship Between Bit-Planes and 24-bit RGB Images

The length of each bit-plane in the time slot is weighted by the corresponding power of 2 of its binary representation. This provides a binary pulse-width modulation of the image. For example, a 24-bit RGB input has three colors with 8-bit depth each. Each color time slot is divided into eight bit-planes, with the sum of all bit-planes in the time slot equal to 256. Figure 4-2 illustrates this partition of bits in a frame.

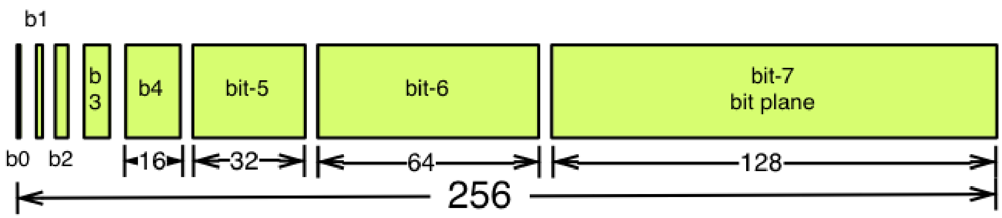


Figure 4-2. Bit Partition

Therefore, a single video frame is composed of a series of bit-planes. Because the DMD mirrors can be either on or off, an image is created by turning on the mirrors corresponding to the bit set in a bit-plane. With binary pulse-width modulation, the intensity level of the color is reproduced by controlling the amount of time the mirror is on. For a 24-bit RGB frame image loaded to the DLPC350, the DLPC350 creates 24 bit-planes, stores them in its internal display buffer, and sends the bit-planes to the DLP4500 DMD, one bit-plane at a time. Depending on the bit weight of the bit-plane, the DLPC350 controls the time this bit-plane is exposed to light, controlling the intensity of the bit-plane. To improve image quality in video frames, the bit-planes, time slots, and color frames are intertwined and interleaved with spatial-temporal algorithms by the DLPC350.

For other applications where this image enhancement is not desired, the video processing algorithms can be bypassed and replaced with a specific set of bit-planes. The bit depth of the pattern is then allocated into the corresponding time slots. Furthermore, an output trigger signal is also synchronized with these time slots to indicate when the image is displayed. For structured light applications, this mechanism provides the capability to display a set of patterns and signals for the camera to capture these patterns overlaid on an object.

As shown in Figure 4-3, the DLPC350 stores two 24-bit frames in its internal memory buffer. This 48 bit-plane display buffer allows the DLPC350 to send one 24-bit buffer to the DMD array while the second buffer is filled from flash or streamed in through the 24-bit Parallel RGB or FPD-link interface. In Streaming mode, the DMD array displays the previous 24-bit frame while the current frame fills the second 24-bit frame of the display buffer. Once a 24-bit frame is displayed, the buffer rotates providing the next 24-bit frame to the DMD. Thus, the displayed image is a 24-bit frame behind the data streamed through the 24-bit RGB Parallel or FPD-link interface.

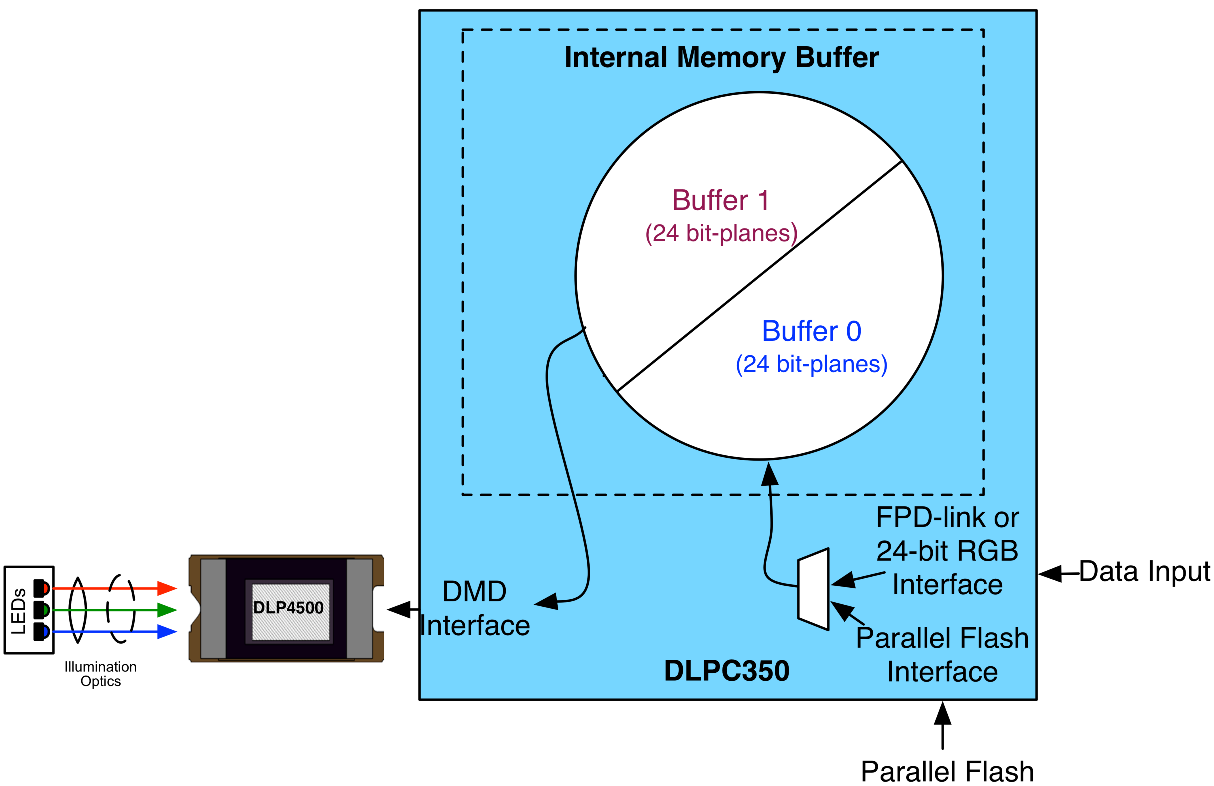


Figure 4-3. DLPC350 Internal Memory Buffer

When the DLP LightCrafter 4500 is set to *Video Mode*, the displayed image is a frame delayed in relation to the data streamed through the RGB parallel interface or FPD-link, as shown in Figure 4-4.

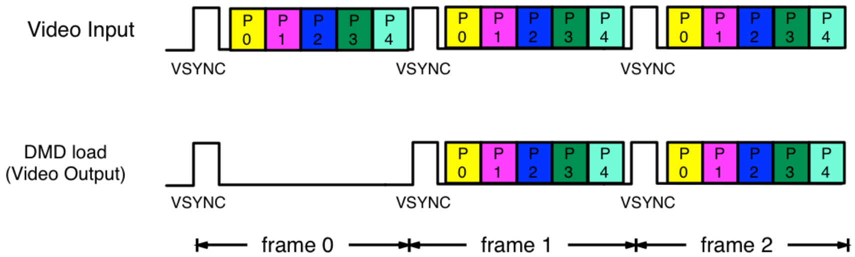


Figure 4-4. Frame Delay Between Parallel Interface Input and Projection Output

When the DLP LightCrafter 4500 is set to *Pattern Sequence* mode with pattern source from flash, the pattern sequence must be loaded from flash memory. The DLPC350 takes at-worst-case 200 ms to load one buffer (24 bit-planes). The actual time to load the buffer is dependent on the complexity of the image. The actual time is provided in the Image / Firmware tab under Image Load Time. If the pattern sequence is less than 24 bit fields, the patterns are displayed from a pre-loaded buffer. Once the patterns are loaded, the pattern sequence repeats from the internal display memory with no buffer load penalty. If the pattern sequence is greater than 24 bit-fields, the 24 bit-field pattern sequence display time must be longer than the full buffer load time. This provides enough time to load the next buffer while the current buffer is displayed. See Figure 4-5 for a diagram of Image Load Time, Pattern Exposure Trigger period, and Internal Trigger period.

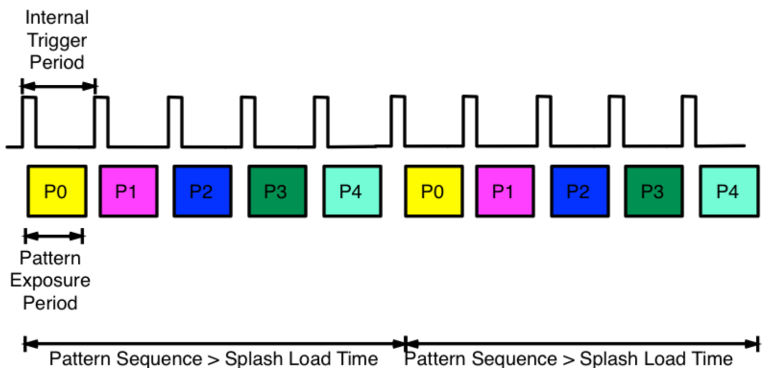


Figure 4-5. Image Load Time and Pattern Sequence Timing

In structured light mode, the 48 bit-planes can be pre-loaded from flash memory and then sequenced with a combination of patterns with different bit depths. To synchronize a camera to the displayed patterns, the DLPC350 supports two trigger inputs and two trigger outputs. TRIG_IN_1 pulse indicates to the DLPC350 to advance to the next pattern, while TRIG_IN_2 starts and stops the pattern sequence. TRIG_OUT_1 frames the exposure time of the pattern, while TRIG_OUT_2 indicates the start of the pattern sequence or internal buffer boundary of 24-bit-planes. For example, in Figure 3-7, the VSYNC starts the pattern sequence display. The pattern sequence consists of a series of three consecutive patterns. The first pattern sequence consists of P1, P2, and P3. Since P3 is an RGB pattern, it is shown with its time sequential representation of P3.1, P3.2, and P3.3. The second pattern sequence consists of three patterns: P4, P5, and P6. The third sequence consists of P7, P8, and P9. TRIG_OUT_1 frames each pattern exposed, while TRIG_OUT_2 indicates the start of each of the three pattern sequences. In Figure 3-8, a pattern sequence of a group of four patterns are displayed. TRIG_OUT_1 frames each pattern exposed, while TRIG_OUT_2 indicates the start of each four-pattern sequence. TRIG_IN_1 pulses advance the pattern.

Table 4-1 shows the allowed pattern combinations in relation to the bit depth of the external pattern.

Table 4-1. Allowable Pattern Combinations

Bit Depth	External RGB Input Pattern Rate (Hz)	Pre-loaded Pattern Rate (Hz)	Minimum Pattern Exposure Period (µs)	Maximum Number of Patterns using Two Buffers (Pre-Loaded)
1-bit	2880	4225	235	48
2-bits	1428	1428	700	24
3-bits	636	636	1570	16
4-bits	588	588	1700	12
5-bits	480	500	2000	8
6-bits	400	400	2500	8
7-bits	222	222	4500	6
8-bits	120	120	8333	6

Saving Solutions

On GUI software version 1.2 or later, any of the parameters set on the GUI can be stored as a solution. This solution can later be recalled with a single button or set to run as default on power-up. Temporary solutions are essentially INI files that contain all the current parameter settings on the GUI. The INI file is stored on the PC. To create a new default solution, you must build the INI file into a new firmware image. This chapter describes the processes for creating, loading, and storing solutions.

5.1 Applying Solutions

This feature refers to the temporary solutions saved as INI files on the PC. Three buttons in the static panel of the GUI control the application and creation of these solutions: **Apply Solution**, **Save Solution**, and **Apply Default Solution**.

- **Save Solution**: Click this button to make a new window with a list of several parameters (described in Section 5.3.1) appear. One column of radio buttons contains the values set in the original DLPC350 firmware. The second column of radio buttons contains the values currently set in the GUI. The user can select either the original or current values to store in the INI file
- **Apply Solution**: Click this button to browse for INI solutions that are already saved. Upon selecting an INI file, the corresponding parameters update in the GUI. Note that parameters the user cannot change in the GUI (version number and splash timeout) do not take effect.
- **Apply Default Solution**: This button restores the settings to match those of the original DLPC350 firmware. Clicking this button is effectively the same as saving a solution and only selecting the values in the first column of radio buttons.

5.2 Changing Default Solutions

This feature refers to the process of taking an INI file and building it into a new firmware image. The following procedure should be followed:

1. Select the “Image / Firmware” tab and the “Add Images to Firmware” sub-tab.
2. Choose a base firmware file. The **Select .ini File** button becomes active and allows the user to browse for an INI file.
3. Once the INI file is selected, click the **Save Updates** button to save a new firmware image file.
4. The last step is to upload this new .bin or .img file to the LightCrafter 4500. The LightCrafter 4500 boots with the settings specified in the INI file, and returns to these settings if reset.

CAUTION

Before saving an INI to firmware, TI recommends to apply the solution first. Wrong values or incorrect syntax can potentially damage the DLP LightCrafter 4500.

5.3 Modifying INI files

There are two ways to modify the INI files. The first method is to use the **Save Solution** button on the GUI. The second method is to open the INI file in a text file editor and edit it manually.

5.3.1 Available Parameters

Table 5-1 shows all available parameters. Please read the Programmer's Guide (DLPU010) for more details.

Table 5-1. List of Available Parameters when Saving Solutions

Parameter Name	Programmer's Guide Command	Extra Notes
APPCONFIG.VERSION.SUBMINOR	Retrieve Firmware Version	Corresponds to: Application software patch number. Range: 0x0000 to 0xFFFF
DEFAULT.AUTOSTART	n/a	0x0 = Boot normally 0x1 = Boot in standby
DEFAULT.DISPMODE	Display Mode Selection	0x0 = Video mode 0x1 = Pattern Display Mode (will start pattern sequence after initialization and splash timeout)
DEFAULT.SHORT_FLIP	Short-Axis Image Flip	0x0 = Disable 0x1 = Enable
DEFAULT.LONG_FLIP	Long-Axis Image Flip	0x0 = Disable 0x1 = Enable
DEFAULT.TRIG_OUT_1.POL	Trigger Out1 Control	0x0 = Active high 0x1 = Active low
DEFAULT.TRIG_OUT_1.RDELAY DEFAULT.TRIG OUT_1.FDELAY	Trigger Out1 Control	Each can range from 0x00 and 0xD5
DEFAULT.TRIG_OUT_2.POL	Trigger Out2 Control	0x0 = Active high 0x1 = Active low
DEFAULT.TRIG_OUT_2.WIDTH	Trigger Out2 Control	Range: 0x00 to 0xFF
DEFAULT.TRIG_IN_1.DELAY	Trigger In1 Control	Range: 0x00 to 0xFF
DEFAULT.TRIG_IN_2.POL	Trigger In2 Control	For Trigger Mode 2 only
DEFAULT.RED_STROBE.RDELAY DEFAULT.RED_STROBE.FDELAY	Red LED Enable Control	Range: 0x00 to 0xFF
DEFAULT.GRN_STROBE.RDELAY DEFAULT.GRN_STROBE.FDELAY	Green LED Enable Control	Range: 0x00 to 0xFF
DEFAULT.BLU_STROBE.RDELAY DEFAULT.BLU_STROBE.FDELAY	Blue LED Enable Control	Range: 0x00 to 0xFF
DEFAULT.INVERTDATA	Pattern Display Invert Data	0x0 = Typical operation 0x1 = Inverted operation
DEFAULT.LEDCURRENT_RED DEFAULT.LEDCURRENT_GRN DEFAULT.LEDCURRENT_BLU	LED Driver Current Control	Range: 0x00 to 0xFF. Note that on this reference design, 0x0 is the maximum PWM, and 0xFF is the minimum. If multiple LEDs are enabled simultaneously (pattern mode or manual operation), then be mindful of maximum current values for design.
DEFAULT.PATTERNCONFIG.PAT_EXPOSURE DEFAULT.PATTERNCONFIG.PAT_PERIOD	Pattern Display Exposure and Frame Period	PAT_EXPOSURE must be less than PAT_PERIOD by at least 230 us, or it must be equal to PAT_PERIOD.
DEFAULT.PATTERNCONFIG.PAT_MODE	Pattern Display Data Input Source	0x0 = Streaming Patterns through video ports 0x3 = Flash memory
DEFAULT.PATTERNCONFIG.TRIG_MODE	Pattern Trigger Mode Selection	0x0 = Vsync Trigger 0x1 = Internal or External Trigger 0x2 = Alternating trigger (not currently in GUI)
DEFAULT.PATTERNCONFIG.PAT_REPEAT	Pattern Display LUT Control	0x0 = Play once 0x1 = Repeat the pattern sequence
DEFAULT.PATTERNCONFIG.NUM_SPLASH	Pattern Display LUT Control	Must be less than 63 (where 0x0 = 1, and 0x3F = 64). Must equal number of items in DEFAULT.SPLASHLUT
DEFAULT.SPLASHLUT	Pattern Display LUT Data - Image Index	Flash image indexes in the order they appear in the pattern sequence. (Example: DEFAULT.SPLASHLUT 0x1 0x2 0x1 0x3 0x0 0x2;)

Table 5-1. List of Available Parameters when Saving Solutions (continued)

Parameter Name	Programmer's Guide Command	Extra Notes
DEFAULT.PATTERNCONFIG.NUM_LUT_ENTRIES	Pattern Display LUT Control	Must be less than 128 (where 0x0 = 1, and 0x7F = 128). Must equal number of items in DEFAULT.SEQPATLUT
DEFAULT.PATTERNCONFIG.NUM_PATTERNS	Pattern Display LUT Control	If PATTERNCONFIG.PAT_REPEAT = 0x0, then should equal number of items in DEFAULT.SEQPATLUT If PAT_REPEAT = 0x1, then should equal number of patterns between desired Trigger Out2 pulses.
DEFAULT.SEQPATLUT	Pattern Display LUT Data – Pattern Definition	Example for two patterns: DEFAULT.SEQPATLUT 0x00042100 0x00002104;
DEFAULT.PORTCONFIG.PORT	Input Source Selection	0x0 = Parallel Interface 0x1 = Internal Test Pattern 0x2 = Flash 0x3 = FPD-Link
DEFAULT.PORTCONFIG.BPP	Input Source Selection	0x0 = 30-bit 0x1 = 24-bit 0x2 = 20-bit 0x3 = 16-bit 0x4 = 8-bit
DEFAULT.PORTCONFIG.PIX_FMT	Input Pixel Data Format	0x0 = RGB 0x1 = YCrCb 444 0x2 = YCrCb 422
DEFAULT.PORTCONFIG.PORT_CLK	Port Clock Select	0x0 = A (needed for this reference design) 0x1 = B 0x2 = C
DEFAULT.PORTCONFIG.ABC_MUX	Input Data Channel Swap Command	0x0 - ABC = ABC 0x1 - ABC = CAB 0x2 - ABC = BCA 0x3 - ABC = ACB 0x4 - ABC = BAC 0x5 - ABC = CBA
DEFAULT.PORTCONFIG.PIX_MODE	FPD-Link Mode and Field Select	0x0 = Mode 1 0x1 = Mode 2 0x2 = Mode 3 0x3 = Mode 4
DEFAULT.PORTCONFIG.SWAP_POL	FPD-Link Mode and Field Select	0x0 = Typical 0x1 = Inverted
DEFAULT.PORTCONFIG.FLD_SEL	FPD-Link Mode and Field Select	0x0 = CONT1 0x1 = CONT2 0x2 = Force 0
PERIPHERALS.I2CADDRESS[0]	I2C Interface in Interface Protocol Section	
PERIPHERALS.I2CADDRESS[1]		
DATAPATH.SPLASHSTARTUPTIMEOUT	n/a	Time in milliseconds before default image times out. Range: 0x0000 to 0xFFFF
DATAPATH.SPLASHSTARTUPENABLE	n/a	0x0 = Do not show a default image when board initializes (power-up or reset) 0x1 = Show a default image when board initializes (power-up or reset)

5.3.2 Save Solution Button

When this button is clicked in the GUI, a new window with a subset of parameters from Table 5-1 appear. One column of radio buttons contains the original values of the DLPC350 firmware. The second column of radio buttons contains the values currently set in the GUI. Select which value or values you want in your INI file. This is the preferred method to prevent syntax errors or invalid entries.

5.3.3 Manual Editing

The INI files can be edited as text files. Note that this method does not check syntax or validate commands. TI recommends this method only for editing those commands not available through the GUI (APPCONFIG.VERSION.SUBMINOR, DEFAULT.AUTOSTART, PERIPHERALS.I2CADDRESS, DATAPATH.SPLASHSTARTUPTIMEOUT, and DATAPATH.SPLASHSTARTUPENABLE). This method can be used with the LUT Helper Tool provided in the software bundle for DEFAULT.SPLASHLUT and DEFAULT.SEQPATLUT. See Section 5.3.4 for more information about the tool.

5.3.4 LUT Entry Helper Tool

The LUT Entry Helper Tool has four tabs. The first two tabs can be used to calculate the values for DEFAULT.SEQPATLUT and DEFAULT.SPLASHLUT. The second two tabs are for reference.

5.3.4.1 Pattern LUT Entries

This tab is used to calculate the values for DEFAULT.SEQPATLUT. The table with 128 possible entries can be modified with the desired parameters for each pattern in the pattern sequence. For each pattern, you can customize various parameters. Valid entries for each category below are found in the Data tab.

- BIT-DEPTH: Select between 1 and 8.
- PATTERN: Select the desired pattern number. Each bit-depth of n corresponds to a pattern number equal to 24 / n. See the Pattern Bit-Planes tab to understand the mapping of bit-planes to pattern number.
- LED: Select which LEDs are on.
- TRIG IN: Select the type of trigger input that will trigger the current pattern. Note that if streaming through the video port, the VSYNC acts as the External Positive trigger, and any subsequent patterns in the frame (between VSYNC pulses) have no trigger. These patterns are labeled with "Continue" in the Pattern Sequence window.
- PAT INVERT: Select whether or not to invert the pattern
- INSERT BLK: Select whether to clear the DMD after each pattern or not. TI recommends that the DMD be cleared at least after the last pattern in the LUT.
- BUFF SWAP: This parameter indicates whether or not to move to the next flash image in the SPLASHLUT. Each time this is a yes, the SPLASHLUT index increments. The index returns to 0 if there are no more indexes.
- TRIG OUT: Either a new Trigger Out1 is generated (NEW) or the pattern shares exposure time with the previous pattern (PREV) and no output trigger is generated.

As the user changes the values in the LUT, the values in the LUT DATA column change. Once the user has entered the parameters for as many patterns as the user needs, scroll to the bottom of the sheet. Enter the total number of patterns next to where it says N = (in cell C138). Then, row 139 generates the necessary values the user needs to copy into the INI file.

Lastly, there is a Debug Helper tool at the bottom of this sheet. Enter a hex code where it says LUT DATA to find out what the corresponding parameters are.

5.3.4.2 Image LUT Entries

This tab is used to calculate the values for DEFAULT.SPLASHLUT. This tab converts the desired image indexes into hexadecimal values. Row 6 contains the calculated string of values for your INI file. If the user repeats indexes, enter them separately. See this example in Table 5-2. The order is 0, 13, 12, 1, 13, 12, 0, 13, 12, 1, 13, 12, and so on.

Table 5-2. Image LUT Entries Example

SL No.	1	2	3	4	5	6
Image Index in Decimal	0	13	12	1	13	12
DEFAULT.SPLASHLUT	0x0	0xD	0xC	0x1	0xD	0xC

PandaBoard Interface

This chapter describes the interface between the DLP LightCrafter 4500 and the PandaBoard ES.

6.1 PandaBoard 4500

PandaBoard ES is a low-cost, open-development platform based on the TI OMAP4 application processor. The PandaBoard ES is supported by a dedicated community at PandaBoard.org. The DLP LightCrafter 4500 combined with a PandaBoard ES provides users with an embedded platform that eliminates the need for a dedicated laptop or PC. The PandaBoard ES includes an OMAP4 1.2 GHz, dual-core processor, 1 GB of onboard RAM, SD card slot, and a suite of connectivity options, including: Ethernet, Bluetooth®, Wi-Fi, USB 2.0, HDMI output and a camera input connector. The combination of PandaBoard ES with DLP LightCrafter 4500 allows for the creation of self-contained, high-precision mobile tools to meet a growing number of applications, such as inline machine vision systems, portable, high-accuracy 3D scanners, and field spectrometers.

To interface a PandaBoard ES with the DLP LightCrafter 4500, the following modifications are needed:

- Populate J1 with Samtec FW-10-04-F-D-570-140
- Populate J3 with Samtec ZW-14-10-F-D-415-200
- Populate J4 with Samtec FW-10-04-F-D-570-140
- Populate J6 with Samtec ZW-14-10-F-D-415-200
- Remove resistor R152 on the PandaBoard ES. The DLP LightCrafter 4500 powers the PandaBoard. Removinf the resistor prevents the PandaBoard from being powered by the USB and conflicting with the DLP LightCrafter 4500 power
- Add four metric male-female threaded hex standoffs with a length of 19 mm and a M3 screw size

Due to the tight tolerances in the J1, J3, J4, and J6 connectors alignment, TI recommends to insert these headers on the corresponding DLP LightCrafter 4500 connector before soldering. For ease of use, SVTronics® has created a custom build option of the PandaBoard ES that includes the connectors and standoffs, and removes the R152 resistor, called PandaBoard 4500. Figure 6-1 shows a DLP LightCrafter 4500 with a PandaBoard 4500.

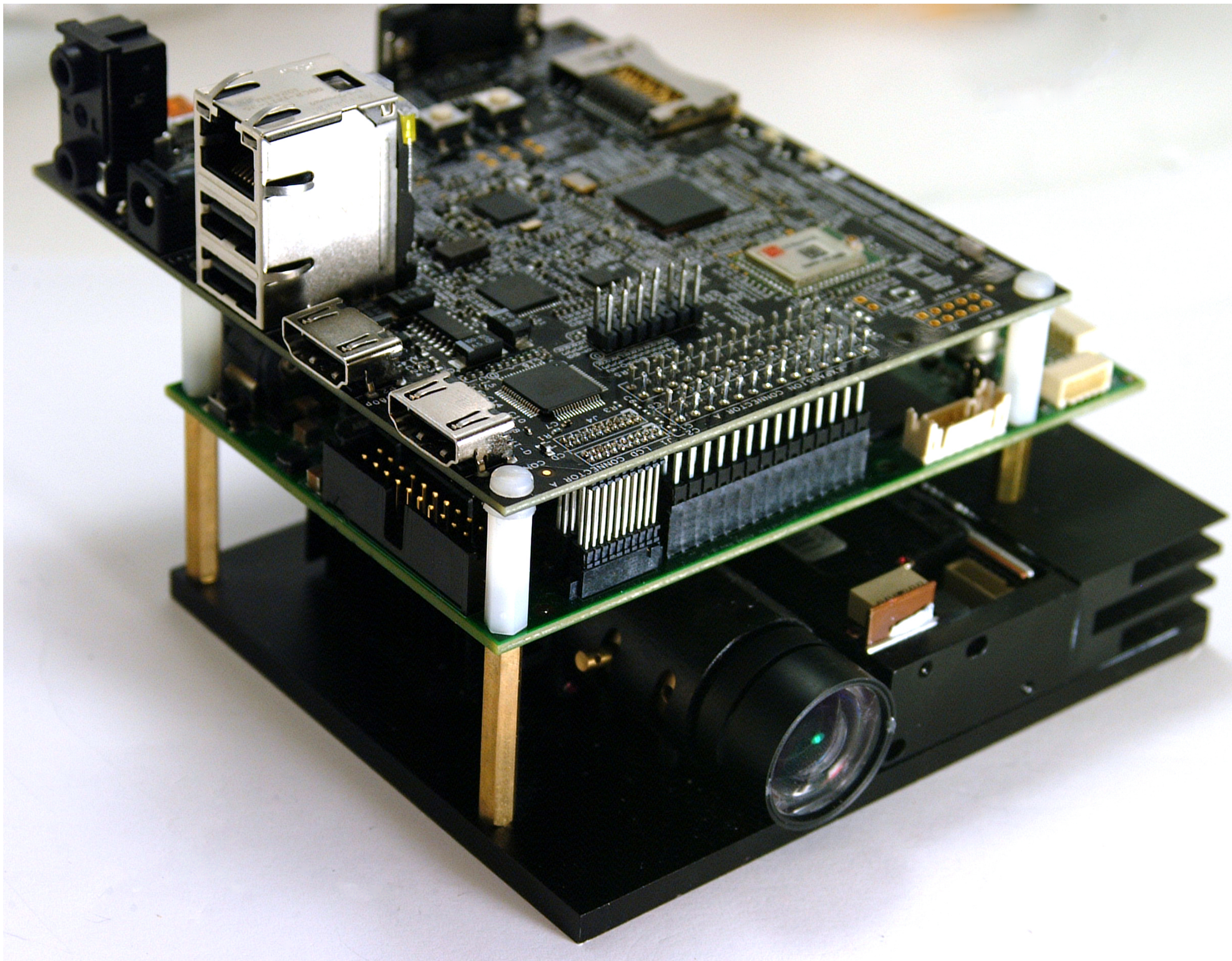


Figure 6-1. DLP LightCrafter 4500 With PandaBoard 4500

6.1.1 DLP LightCrafter 4500 to PandaBoard Interface

As shown in Figure 6-2, the DLP LightCrafter 4500 supplies 5-V power to the PandaBoard. The PandaBoard provides 1.8 V to the DLP LightCrafter 4500 to level shift all the signals interfacing the two boards together. The following OMAP4 GPIOs control the routing of OMAP4 peripherals to the corresponding DLPC350 peripherals:

- To power down the output of TFP401 and enable the level shifters in the 24-bit RGB interface, the OMAP4 must drive GPIO_140 (SYS_MSTR_MUX_SEL) high.
- To connect the OMAP4 USB3 bus to the DLC350, OMAP4 must drive GPIO_39 (SYS_USB_SEL) high.
- To connect the OMAP4 I2C2 bus to the DLPC350 I2C1 bus, OMAP4 must drive GPIO_51 (SYS_I2C_OE) high.
- To disconnect UART output of DLPC350 from J20 and route it to OMAP4 UART4, OMAP4 must drive GPIO_33 high.
- To connect the Triggers from DLPC350 to OMAP4 GPIOs, OMAP4 must drive GPIO_61 (SYS_TRIGGER_SEL) high.

Table 6-1, Table 6-2, Table 6-3, and Table 6-4 list the signals interfacing the OMAP4 in the PandaBoard 4500 with the DLPC350 in the DLP LightCrafter 4500:

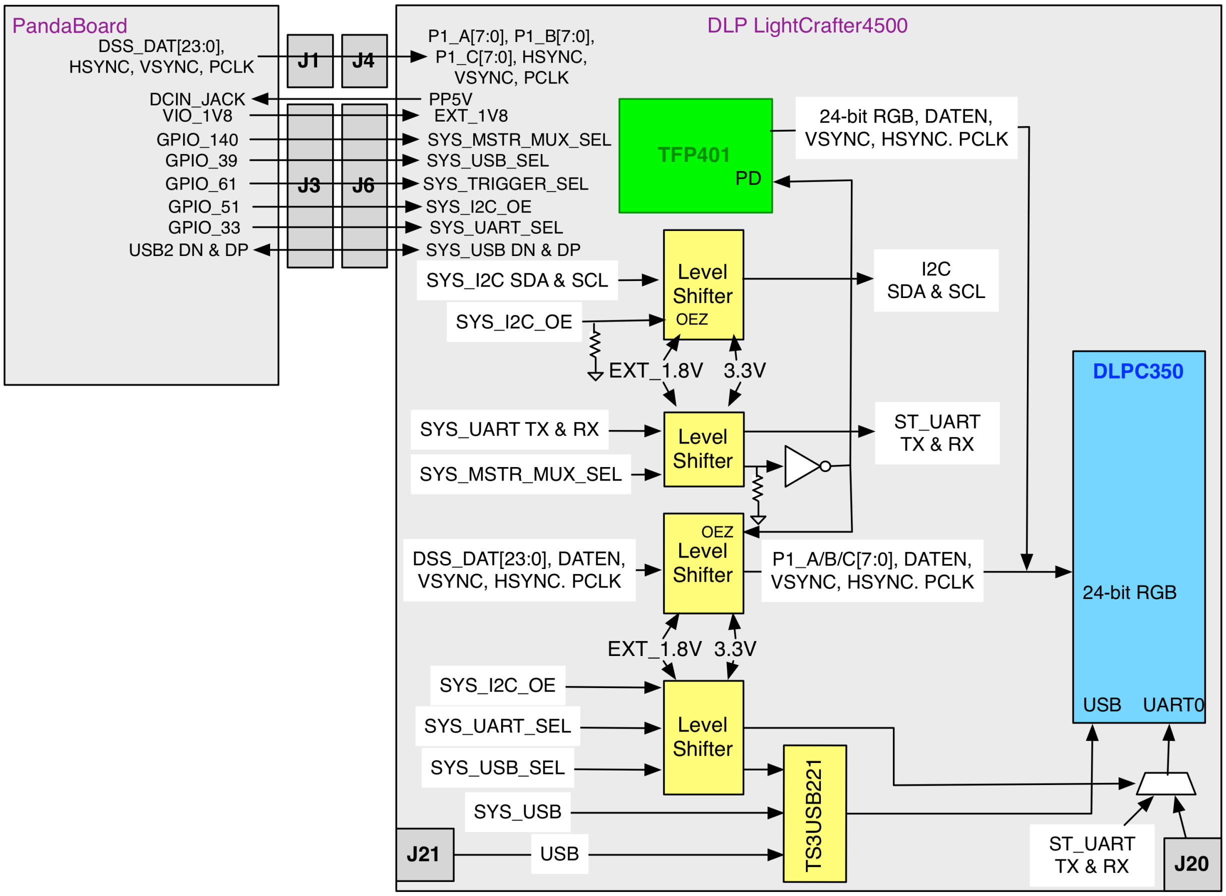


Figure 6-2. Block Diagram of the PandaBoard Interface

Table 6-1. J1 PandaBoard 4500 to DLP LightCrafter 4500 Interface

PandaBoard 4500 J1				DLP LightCrafter 4500 J1			
Pin	**Signal**	**I/O**	**Description**	**Pin**	**Signal**	**I/O**	**Description**
1	DCIN_JACK	PWR	5 V supplied from DLP LightCrafter 4500	1	PP5P0V	PWR	5 V supplied by TLV62130 (U28) of DLP LightCrafter 4500
2	DCIN_JACK	PWR	5 V supplied from DLP LightCrafter 4500	2	PP5P0V	PWR	5 V supplied by TLV62130 (U28) of DLP LightCrafter 4500
3	h_DSS_DAT1	O	OMAP4 LCD pixel data bit 1	3	SYS_DATA01	I	DLPC350 P1_A_3 level shifted to 1.8 V
4	h_DSS_DAT0	O	OMAP4 LCD pixel data bit 0	4	SYS_DATA00	I	DLPC350 P1_A_2 level shifted to 1.8 V
5	h_DSS_DAT3	O	OMAP4 LCD pixel data bit 3	5	SYS_DATA03	I	DLPC350 P1_A_5 level shifted to 1.8 V
6	h_DSS_DAT2	O	OMAP4 LCD pixel data bit 2	6	SYS_DATA02	I	DLPC350 P1_A_4 level shifted to 1.8 V
7	h_DSS_DAT5	O	OMAP4 LCD pixel data bit 5	7	SYS_DATA05	I	DLPC350 P1_A_7 level shifted to 1.8 V
8	h_DSS_DAT4	O	OMAP4 LCD pixel data bit 4	8	SYS_DATA04	I	DLPC350 P1_A_6 level shifted to 1.8 V
9	h_DSS_DAT12	O	OMAP4 LCD pixel data bit 12	9	SYS_DATA12	I	DLPC350 P1_B_6 level shifted to 1.8 V
10	h_DSS_DAT10	O	OMAP4 LCD pixel data bit 10	10	SYS_DATA010	I	DLPC350 P1_B_4 level shifted to 1.8 V
11	h_DSS_DAT23	O	OMAP4 LCD pixel data bit 23	11	SYS_DATA23	I	DLPC350 P1_C_9 level shifted to 1.8 V
12	h_DSS_DAT14	O	OMAP4 LCD pixel data bit 14	12	SYS_DATA14	I	DLPC350 P1_B_8 level shifted to 1.8 V
13	h_DSS_DAT19	O	OMAP4 LCD pixel data bit 19	13	SYS_DATA19	I	DLPC350 P1_C_5 level shifted to 1.8 V
14	h_DSS_DAT22	O	OMAP4 LCD pixel data bit 22	14	SYS_DATA22	I	DLPC350 P1_C_8 level shifted to 1.8 V
15	H_I2C2_SDA	I/O	OMAP4 I2C2 Serial Data	15	SYS_I2C1_SDA	I/O	DLPC350 I2C1_SDA level shifted to 1.8 V
16	h_DSS_DAT11	O	OMAP4 LCD pixel data bit 11	16	SYS_DATA11	I	DLPC350 P1_B_5 level shifted to 1.8 V
17	h_DSS_VSYNC	O	OMAP4 LCD Vertical Sync Signal	17	SYS_VSYNC	I	DLPC350 P1_VSYNC level shifted to 1.8 V
18	H_DPM_EMU2	I	DPM_EMU2/GPIO_13	18	NC		No Connect
19	GND	GND	Ground bus	19	GND	GND	Ground bus
20	GND	GND	Ground bus	20	GND	GND	Ground bus

Table 6-2. J3 PandaBoard 4500 to DLP LightCrafter 4500 Interface

PandaBoard 4500 J3				DLP LightCrafter 4500 J3			
Pin	**Signal**	**I/O**	**Description**	**Pin**	**Signal**	**I/O**	**Description**
1	VIO_1V8	PWR	Panda 1.8 V system I/O voltage	1	EXT_1V8	PWR	1.8 V supplied by Panda
2	DCIN_JACK	PWR	5 V supplied from DLP LightCrafter 4500	2	PP5P0V	PWR	5 V supplied by TLV62130 (U28) of DLP LightCrafter 4500
3	GPMC_AD7	I/O	OMAP4 GPMC address or data bit 7	3	NC		No connect
4	MCSPI1_CS3 / GPIO_140	O	OMAP4 SPI1 Chip Select 3 (also UART1_RTS)	4	SYS_MASTER_MUX_SEL	I	When High, Panda enables the level shifters, muxes the RGB signals to DLPC350, and disables TFP401. When Low, RGB signals are muxed to TFP401 and level shifters to Panda are disabled
5	GPMC_AD6	I/O	OMAP4GPMC address or data bit 6	5	NC		No connect
6	UART4_TX	O	OMAP4 UART4 transmit data	6	SYS_UART0_RX	I	DLPC350 UART0_RX level shifted to 1.8 V
7	GPMC_AD5	I/O	OMAP4 GPMC address or data bit 5	7	NC		No connect
8	UART4_RX	I	OMAP4 UART4 receive data	8	SYS_UART0_TX0	O	DLPC350 UART0_TX level shifted to 1.8 V. Outputs error info from DLPC350
9	GPMC_AD4	I/O	OMAP4 GPMC address or data bit 4	9	NC		No connect
10	MCSPI1_CS1 / GPIO_138	O	OMAP4 SPI1 chip select 1 (also UART1_RX)	10	SYS_TRIG_IN_1	I	DLPC350 TRIG_IN_1 level shifted to 1.8 V. This signal advances the pattern during *Pattern Sequence* mode
11	GPMC_AD3	I/O	OMAP4GPMC address or data bit 3	11	NC		No connect
12	MCSPI1_SIMO / GPIO_136	I/O	OMAP4 SPI1 slave in master out	12	SYS_TRIG_IN_2	I	DLPC350 TRIG_IN_2 level shifted to 1.8 V. This signal is used as a start (rising edge) or stop (falling edge) during *Pattern Sequence* mode.
13	GPMC_AD2	I/O	OMAP4 GPMC address or data bit 2	13	NC		No connect
14	MCSPI1_CS2 / GPIO_139	O	OMAP4 SPI1 chip select 2 (also UART1_CTS)	14	DRV_EXT_POWER_ON	O	DLPC350 EXT_POWER_ON level shifted to 1.8 V. This signal indicates to OMAP4 the DLPC350 is powered ON.
15	GPMC_AD1	I/O	OMAP4 GPMC address or data bit 1	15	NC		No connect
16	MCSPI1_CS0 / GPIO_137	I/O	OMAP4 SPI1 chip select 0	16	DRV_TRIG_OUTB_2	O	DLPC350 TRIG_OUT_2 level shifted to 1.8 V. DLPC350 active high signal to indicate first pattern in *Pattern Sequence* mode.
17	GPMC_AD0	I/O	OMAP4 GPMC address or data bit 0	17	NC		No Connect
18	MCSPI1_SOMI / GPIO_135	I/O	OMAP4 SPI1 slave out master I	18	DRV_TRIG_OUTB_1	O	DLPC350 TRIG_OUT_2 level shifted to 1.8 V. DLPC350 active high pattern exposure signal during *Pattern Sequence* mode
19	GPMC_NWE	O	OMAP4 GPMC write enable	19	NC		No connect
20	MCSPI1_CLK / GPIO_134	I/O	OMAP4 SPI1 clock out	20	DRV_INIT_DONE	O	DLPC350INTI_DONE level shifted to 1.8 V. DLPC350 active high pulse signal to indicate system initialization is complete
21	GPMC_NOE	O	OMAP4 GPMC output enable	21	NC		No connect
22	GPMC_AD15 / GPIO_39	I/O	OMAP4 GPMC address or data bit 15	22	SYS_USB_SEL	I	Signal from OMAP4 to switch the TS3USB221 mux. When low, driver board USB connector is routed to DLPC350. When high, OMAP4 drives USB to DLPC350
23	I2C4_SDA	I/O	OMAP4 I2C4 serial data	23	NC		No connect
24	I2C4_SCL	O	OMAP4 I2C4 serial clock	24	NC		No connect
25	REGEN1	O	Panda TWL6030 REGEN1	25	NC		No connect
26	SYS_NRESPWRON	O	Panda power-on reset	26	NC		No connect
27	DGND	GND	Digital ground	27	GND	GND	Digital ground
28	DGND	GND	Digital ground	28	GND	GND	Digital ground

Table 6-3. J4 PandaBoard 4500 to DLP LightCrafter 4500 Interface

PandaBoard 4500 J4				DLP LightCrafter 4500 J4			
Pin	Signal	I/O	Description	Pin	Signal	I/O	Description
1	VDD_V AUX2	PWR	Panda Power rail (adjustable from 1.2 V to 2.8 V)	1	NC		No connect
2	VIO_1V8	PWR	Panda 1.8 V system I/O voltage	2	EXT_1V8	PWR	1.8 V supplied by Panda
3	h_DSS_DAT20	O	OMAP4 LCD pixel data bit 20	3	SYS_DATA20	I	DLPC350 P1_C_6 level shifted to 1.8 V
4	h_DSS_DAT21	O	OMAP4 LCD pixel data bit 21	4	SYS_DATA21	I	DLPC350 P1_C_7 level shifted to 1.8 V
5	h_DSS_DAT17	O	OMAP4 LCD pixel data bit 17	5	SYS_DATA17	I	DLPC350 P1_C_3 level shifted to 1.8 V
6	h_DSS_DAT18	O	OMAP4 LCD pixel data bit 18	6	SYS_DATA18	I	DLPC350 P1_C_4 level shifted to 1.8 V
7	h_DSS_DAT15	O	OMAP4 LCD pixel data bit 15	7	SYS_DATA15	I	DLPC350 P1_B_9 level shifted to 1.8 V
8	h_DSS_DAT16	O	OMAP4 LCD pixel data bit 16	8	SYS_DATA16	I	DLPC350 P1_C_2 level shifted to 1.8 V
9	h_DSS_DAT7	O	OMAP4 LCD pixel data bit 7	9	SYS_DATA7	I	DLPC350 P1_A_9 level shifted to 1.8 V
10	h_DSS_DAT13	O	OMAP4 LCD pixel data bit 13	10	SYS_DATA13	I	DLPC350 P1_B_7 level shifted to 1.8 V
11	h_DSS_DAT8	O	OMAP4 LCD pixel data bit 8	11	SYS_DATA8	I	DLPC350 P1_B_2 level shifted to 1.8 V
12	NUSB_PWR	O	Input power enable	12	NC		No connect
13	h_DSS_DAT9	O	OMAP4 LCD pixel data bit 9	13	SYS_DATA09	I	DLPC350 P1_B_3 level shifted to 1.8 V
14	H_I2C2_SCL	O	OMAP4 I2C2 serial clock	14	SYS_I2C1_SCL	I	DLPC350 I2C1_SCL level shifted to 1.8 V
15	h_DSS_DAT6	I/O	OMAP4 LCD pixel data bit 6	15	SYS_DATA06	I/O	DLPC350 P1_A_8 level shifted to 1.8 V
16	h_DSS_PCLK	O	OMAP4 LCD pixel clock	16	SYS_PCLK	I	DLPC350 P1_CLK level shifted to 1.8 V
17	h_DSS_DEN	O	OMAP4 LCD data enable	17	SYS_DATA_EN	I	DLPC350 P1_DATAEN level shifted to 1.8 V
18	h_DSS_HSYNC	O	OMAP4 LCD horizontal sync	18	SYS_HSYNC	I	DLPC350 P1_HSYNC level shifted to 1.8 V
19	GND	GND	Ground bus	19	GND	GND	Digital ground
20	GND	GND	Ground bus	20	GND	GND	Digital ground

Table 6-4. J6 PandaBoard 4500 to DLP LightCrafter 4500 Interface

PandaBoard 4500 J6				DLP LightCrafter 4500 J6			
Pin	Signal	I/O	Description	Pin	Signal	I/O	Description
1	VBUS_3	PWR	OMAP4 VBUS output from USB Host Port #3	1	NC		No connect
2	VBUS_4	PWR	OMAP4 VBUS output from USB Host Port #4	2	NC		No connect
3	USBH3_DM	I/O	OMAP4 USB host port 3 data minus	3	SYS_USB_DN	I/O	TS3USB221 USB DN
4	USBH4_DM	I/O	OMAP4 USB host port 4 data minus	4	NC		No connect
5	USBH3_DP	I/O	OMAP4 USB host port 3 data plus	5	SYS_USB_DP	I/O	TS3USB221 USB DP
6	USBH4_DP	I/O	OMAP4 USB host port 4 data plus	6	NC		No connect
7	DGND	GND	Digital ground	7	GND	GND	Digital ground
8	DGND	GND	Digital ground	8	GND	GND	Digital ground
9	GPMC_AD14 / GPIO_38	I/O	OMAP4 GPMC address or data bit 14	9	DRV_GPIO11	O	DLPC350 GPIO11 (ClockC output) level shifted to 1.8 V
10	GPMC_AD13 / GPIO_37	I/O	OMAP4 GPMC address or data bit 13	10	DRV_GPIO12	O	DLPC350 GPIO12 (ClockD output) level shifted to 1.8 V
11	SYS_NRESWARM	I/O	Panda Warm Reset	11	NC		No connect
12	PB_POWER_ON	I	Power on input to TWL6030 (ref. to VBAT)	12	NC		No connect
13	HFL_P	O	Hands free left speaker out (+)	13	NC		No connect
14	H_DMTIMER11_PWM / GPIO121	O	OMAP4 display PWM control	14	SYS_GPIO5	I	DLPC350 GPIO5 (PWM0 input) level shifted to 1.8 V
15	HFL_N	O	Hands free left speaker out (–)	15	NC		No connect
16	VDD_V AUX1	PWR	TWL6030 VAUX1	16	NC		No connect
17	GPMC_AD12 / GPIO_36	I/O	OMAP4 GPMC address or data bit 13	17	SYS_GPIO6	I	DLPC350 GPIO6 (PWM1 input) level shifted to 1.8 V
18	GPMC_AD8 / GPIO_32	I/O	OMAP4 GPMC address or data bit 8	18	DRV_GPIO00	O	DLPC350 GPIO0 (PWM0 output) level shifted to 1.8 V
19	GPMC_W AIT0 / GPIO_61	I	OMAP4 GPMC Wait input 0	19	SYS_TRIGGER_SEL	I	When high routes DLPC350 Trigger Inputs to Panda. When low routesDLPC350 Trigger Inputs to DLP LightCrafter 4500 input trigger connector
20	GPMC_AD9 / GPIO_33	I/O	OMAP4 GPMC address or data bit 9	20	SYS_UART_SEL	I	When high routes the DLPC350 UART to Panda. When low routes the DLPC350 UART to the DLP LightCrafter 4500 UART connector

Table 6-4. J6 PandaBoard 4500 to DLP LightCrafter 4500 Interface (continued)

PandaBoard 4500 J6				DLP LightCrafter 4500 J6			
Pin	Signal	I/O	Description	Pin	Signal	I/O	Description
21	GPMC_NWP / GPIO_54	O	OMAP4 GPMC write protect	21	NC		No connect
22	GPMC_AD10 / GPIO_34	I/O	OMAP4 GPMC address or data bit 10	22	DRV_GPIO02	O	DLPC350 GPIO2 (PWM2 output) level shifted to 1.8 V
23	GPMC_CLK / GPIO_55	O	OMAP4 GPMC Clock Out	23	NC		No connect
24	GPMC_AD11 / GPIO_35	I/O	OMAP4 GPMC address or data bit 11	24	DRV_TRIG_OUTA_1	O	External Trigger Input from Connector J11 TRIG1_IN_CONN level shifted to 1.8 V
25	GPMC_NCS0 / GPIO_50	O	OMAP4 GPMC Chip Select 0	25	DRV_TRIG_OUTA_2	O	External Trigger Input from Connector J11 TRIG2_IN_CONN level shifted to 1.8 V
26	GPMC_NADV_ALE / GPIO_56	O	OMAP4 GPMC address valid or address latch enable	26	NC		No connect
27	GPMC_NCS1 / GPIO_51	O	OMAP4 GPMC Chip Select 1	27	SYS_I2C_OE	I	When high, connects the OMAP4 I2C2 bus to DLPC350 I2C1 bus. When low, disconnects the OMAP4 I2C2 bus from the DLPC350 I2C1 bus
28	GPMC_NBE0_CLE / GPIO_59	O	OMAP4 GPMC byte enable 0 or command latch enable	28	NC		No connect

6.1.2 PandaBoard Software

The HDMI connector is the default display output of PandaBoard. To reroute the display video output to the RGB onterface of the DLP LightCrafter 4500, the kenrel config file must be modified with the following changes:

- DIsable DRM
- Enable DVI output
- Enable Frame Buffer support

To perform these changes, obtain the Ubuntu® kernel from the repository:

- git clone git://kernel.ubuntu.com/ubuntu/ubuntu-precise.git
- git checkout -b working origin/ti-omap4

Install ARM compilers on Linux machine:

- sudo apt-get install gcc-arm-linux-gnueabihf cpp-arm-linux-gnueabihf
- sudo apt-get install gcc-arm-linux-gnueabi cpp-arm-linux-gnueabi

To run the menuconfig, insall ncurses package:

- sudo apt-get install build-essential ncurses-dev

Before compiling the Ubuntu kernel, the DVI port needs to be enabled. Run menuconfig:

- cp debian.ti-omap4/config/config.common.ubuntu.config
- sudo make ARCH=arm menuconfig

Select the following:

- Disable DRM under: Device Drivers → Graphics Support → Direct Rendering Manager
- Enable DVI under: Device Drivers → Graphic Support → OMAP2+ Display Subsystem support → OMAP2/3 Display Device Drivers → DVI Output
- Enable Frame Buffer support: Device Drivers → Graphic Support → OMAP2+ Display Subsystem support → OMAP2+ frame buffer support

Build the kernel:

- ARCH=arm CROSS_COMPILE=arm-linux-gnueabi- make

Generate the uImage:

- ARCH=arm CROSS_COMPILE=arm-linux-gnueabi- make uImage

The generated uImage will be located at ubuntu-precise/arch/arm/boot/uImage.

To configure the OMAP4 LCD peripheral drive for the DLP LightCrafter 4500 24-bit RGB input, perform the following changes to the boot script. The boot script, boot.scr, is used by u-boot.

- Set the DVI as the default output by adding the following entry to boot.scr:
  - omapfb.mode=dvi omapdss.def_disp=dvi
- Set the desired resolution fro the DLP LightCrafter 4500 output by adding one of the following entries to boot.scr:
  - omapfb.mode=dvi:912x1140MR-24@60
  - omapfb.mode=dvi:1280x800MR-24@60
- Generate the boot.scr:
  - mkimage -A arm -T script -C none -n "Boot Image" -d boot.script boot.scr
- Copy the generated uImage and boot.scr in the boot partition of the SD card.

Make the modules:

- make CROSS_COMPILE=arm-linux-gnueabi- ARCH=arm INSTALL_MOD_PATH=<path_of_modules> modules_install

Copy the ‘modules’ folder from the path given in above command to the \lib folder on secondary partition.

Connectors

This chapter describes the connector pins of the DLP LightCrafter 4500 Module.

7.1 Input Trigger Connectors

The input trigger connector (J11) pins are listed in Table 7-1. The trigger inputs have hysteresis. Two matching six-pin, 1.25-mm connector part numbers are:

- Molex part number: 51021-0600
- Digi-Key part number: WM1724-ND

The corresponding connector terminal (crimp) part numbers are:

- Molex part number: 50079-8100
- Digi-Key part number: WM2023-ND

Table 7-1. Input Trigger Connector Pins

Description	Pin	Supply Range
Trigger In 1 Supply	1	External or internal 1.8-V, 3.3-V, and 5-V selectable at J10
Trigger In 1	2	
Ground	3	Ground
Trigger In 2 Supply	4	External or internal 1.8-V, 3.3-V, and 5-V selectable at J12
Trigger In 2	5	
Ground	6	Ground

7.2 Output Trigger Connectors

The output trigger connector (J14) pins are listed in Table 7-2. Two matching six-pin, 1.25-mm connector part numbers are:

- Molex part number: 51021-0600
- Digi-Key part number: WM1724-ND

The corresponding connector terminal (crimp) part numbers are:

- Molex part number: 50079-8100
- Digi-Key part number: WM2023-ND

Table 7-2. Output Trigger Connector Pins

Description	Pin	Supply Range
Trigger Out 1 Supply	1	1.8-V, 3.3-V, and 5-V selectable at J13
Trigger Out 1	2	
Ground	3	Ground
Trigger Out 2 Supply	4	1.8-V, 3.3-V, and 5-V selectable at J15
Trigger Out 2	5	
Ground	6	Ground

7.3 DLPC350 UART

The DLPC350 UART compatible cable:

- Leopard Imaging: LI-SER-01
- Mouser part number: 931-LI-SER-01

The UART connector (J20) pins are shown in Table 7-3.

Table 7-3. UART Connector Pins

Description	Pin	Supply Range
Ground	1	0 V
RX	2	3.3 V
TX	3	3.3 V

7.4 DLPC350 I^2C0

The I^2C0 connector (J16) pins are shown in Table 7-5. Two matching four-pin, 1.25-mm connector part numbers are:

- Molex part number: 51021-0400
- Digi-Key part number: WM1722-ND

The corresponding terminal (crimp) part numbers are:

- Molex part number: 50079-8100
- Digi-Key part number: WM2023-ND

Table 7-4. I^2C0 Connector Pins

Description	Pin	Supply Range
I^2C SCL	1	3.3 V
I^2C SDA	2	3.3 V
3.3-V supply	3	3.3 V
Ground	4	0 V

7.5 DLPC350 I^2C1

The I^2C1 connector (J17) pins are shown in Table 7-4. Two matching four-pin, 1.25-mm connector part numbers are:

- Molex part number: 51021-0400
- Digi-Key part number: WM1722-ND

The corresponding terminal (crimp) part numbers are:

- Molex part number: 50079-8100
- Digi-Key part number: WM2023-ND

Table 7-5. I^2C1 Connector Pins

Description	Pin	Supply Range
I^2C SCL	1	3.3 V
I^2C SDA	2	3.3 V
3.3-V supply	3	3.3 V
Ground	4	0 V

7.6 Fan

The fan connector (J22) pins are shown in Table 7-6. Two matching three-pin, 1.25-mm connector part numbers are:

- Molex part number: 51021-0300
- Digi-Key part number: WM1722-ND

The corresponding terminal (crimp) part numbers are:

- Molex part number: 50079-8100
- Digi-Key part number: WM2023-ND

Table 7-6. Fan Connector Pins

Description	Pin	Supply Range
Power	1	12 V
FAN_LOCKED	2	3.3 V
Ground	3	0 V

7.7 Red LED

The Red LED connector (J31) pins are shown in Table 7-7. Two matching nine-pin, 1.5-mm connector part numbers are:

- Molex part number: 87439-0900
- Digi-Key part number: WM2093-ND

The corresponding terminal (crimp) part numbers are:

- Molex part number: 87421-0000
- Digi-Key part number: WM1112-ND

Table 7-7. Red LED Connector Pins

Description	Pin	Supply Range
Ground	1	0 V
Temperature sensor	2	3.3 V
3.3-V supply	3	3.3 V
Red anode	4	3 V
Red anode	5	3 V
Red anode	6	3 V
Red cathode	7	0 V
Red cathode	8	0 V
Red cathode	9	0 V

7.8 Green LED

The Green LED connector (J32) pins are shown in Table 7-8. Two matching six-pin, 1.5-mm connector part numbers are:

- Molex part number: 87439-0600
- Digi-Key part number: WM2093-ND

The corresponding terminal (crimp) part numbers are:

- Molex part number: 87421-0000
- Digi-Key part number: WM1112-ND

Table 7-8. Green LED Connector Pins

Description	Pin	Supply Range
Green anode	1	4.3 V
Green anode	2	4.3 V
Green anode	3	4.3 V
Green cathode	4	0 V
Green cathode	5	0 V
Green cathode	6	0 V

7.9 Blue LED

The Blue LED connector (J33) pins are shown in Table 7-9. Two matching six-pin, 1.5-mm connector part numbers are:

- Molex part number: 87439-0600
- Digi-Key part number: WM2093-ND

The corresponding terminal (crimp) part numbers are:

- Molex part number: 87421-0000
- Digi-Key part number: WM1112-ND

Table 7-9. Blue LED Connector Pins

Description	Pin	Supply Range
Blue anode	1	4.3 V
Blue anode	2	4.3 V
Blue anode	3	4.3 V
Blue cathode	4	0 V
Blue cathode	5	0 V
Blue cathode	6	0 V

7.10 FPD-Link

The FPD-Link connector (J9) pins are shown in Table 7-10. The 20 pin, 0.5 SMT header is:

- Panasonic part number: AXK6S20647YG

Table 7-10. FPD-Link Connector Pins

Description	Pin	Supply Range
RCK_IN_P	1	1.2 V
RXE_AP	2	1.2 V
Ground	3	0 V
Ground	4	0 V
RCK_IN_N	5	1.2 V
RXE_AN	6	1.2 V
RXE_BP	7	1.2 V
RXE_CP	8	1.2 V
Ground	9	0 V
Ground	10	0 V
RXE_BN	11	1.2 V
RXE_CN	12	1.2 V
RXE_DP	13	1.2 V
RXE_EP	14	1.2 V

Table 7-10. FPD-Link Connector Pins (continued)

Description	Pin	Supply Range
Ground	15	0 V
Ground	16	0 V
RXE_DN	17	1.2 V
RXE_EN	18	1.2 V
NC	19	n/a
NC	20	n/a

7.11 JTAG Boundary Scan

The JTAG Boundary connector (J25) pins are listed in Table 7-11. Two matching six-pin, 1.25-mm connector part numbers are:

- Molex part number: 51021-0600
- Digi-Key part number: WM1724-ND

The corresponding connector terminal (crimp) part numbers are:

- Molex part number: 50079-8100
- Digi-Key part number: WM2023-ND

Table 7-11. JTAG Boundary Scan Connector Pins

Description	Pin	Supply Range
$\overline{\text{TRST}}$	1	3.3 V
TDI	2	3.3 V
TMS1	3	3.3 V
TDO1	4	3.3 V
TCK	5	3.3 V
Ground	6	Ground

7.12 Power

The power socket (J26) pins are shown in Table 7-12. Two matching connector part numbers are:

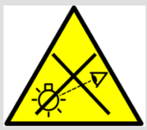
- Switchcraft part number: 760
- Digi-Key part number: SC1051-ND

Table 7-12. Power Connector Pins

Description	Pin	Supply Range
Input Supply	1	12 V
Ground	2	0 V
Ground	3	0 V

Safety

WARNING




Possible hazardous optical radiation emitted from this product. Do not stare at operating LEDs. May be harmful to eyes. Also, avoid touching components during operation.

CAUTION

To minimize the risk of fire or equipment damage, make sure that air is allowed to circulate freely around the DLP LightCrafter 4500 board when operating.

CAUTION

The kit contains ESD-sensitive components. Handle with care to prevent permanent damage.

Power Supply Requirements

B.1 External Power Supply Requirements

The DLP LightCrafter 4500 does not include a power supply. The external power supply requirements are:

- Nominal voltage: 12-V DC
- Minimum current: 0 A
- Maximum Current: 7 A
- DC connector size:
  - Inner diameter: 2.5 mm
  - Outer diameter: 5.5 mm
  - Shaft: 9.5-mm female, center positive
- Efficiency level: V

NOTE: External Power Supply Regulatory Compliance Certifications: Recommend selection and use of an external power supply, which meets TI's required minimum electrical ratings in addition to complying with applicable regional product regulatory and safety certification requirements such as (by example) UL, CSA, VDE, CCC, PSE, and so forth.

Revision History

Changes from A Revision (September 2013) to B Revision **Page**

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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