DLP® LightCrafter™ Evaluation Module (EVM)

User's Guide

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Read This First

About This Guide

The DLP® LightCrafter™ is a third party implementation of a next generation DLP 0.3-inch WVGA chipset 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 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.

Figure 1. DLP LightCrafter Evaluation Module

Related Documentation from Texas Instruments

- DLPC300 data sheet: *DLP Digital Controller for DLP3000 DMD*, TI literature number DLPS023
- DLP3000 data sheet: *DLP 0.3 WVGA DDR Series 220 DMD*, TI literature number DLPS022
- *DLPC300 Software Programmer's Guide*, TI literature number DLPU004
- *DLP® LightCrafter™ DM365 Command Interface Guide*, TI literature number DLPU007
- *DLP® LightCrafter™ FPGA Overview* TI literature number DLPA042
- *Using the DLP® LightCrafter™ to Trigger CCD Cameras from The Image Source®* TI literature number DLPA032
- *Creating Multiple Bit Depth and Multiple Color Pattern Sequences for DLP® LightCrafter™ Kit* TI literature number DLPA035

If You Need Assistance

Refer to the DLP and MEMS TI E2E community support forums.

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DLP® LightCrafter™ Module Overview

This chapter introduces the DLP LightCrafter module.

1.1 Welcome

Your new DLP LightCrafter module allows you to evaluate TI's DLP 0.3-inch WVGA chipset platform along with TI's DaVinci Technology and the DM365 architecture.

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

- Small display projector: embedded display, interactive display, information overlay
- Structured light applications: 3D modeling/design, biometric: fingerprint identification and face recognition, machine vision and inspection
- Medical and life sciences: vascular imaging, dental impression scanner, intraoral dental scanners, orthopaedics, prosthesis, CT/MRI/X-ray marking, retail cosmetics

1.2 What is in the LightCrafter EVM?

The DLP LightCrafter module consists of three subsystems:

- Light engine – includes the optics, red, green, and blue LEDs, and the 608 × 684 diamond pixel 0.3-inch WVGA DMD. Capable of 20 lumens out-of-the-box with support to 50 lumens with user's addition of active cooling.
- Driver board – includes the LED driver circuits, DLPC300 DMD Controller, power management circuits, and MSP430.
- System board – includes TMS320DM365, FPGA, and several connectors for external inputs.

Figure 1-1 shows the major hardware components.

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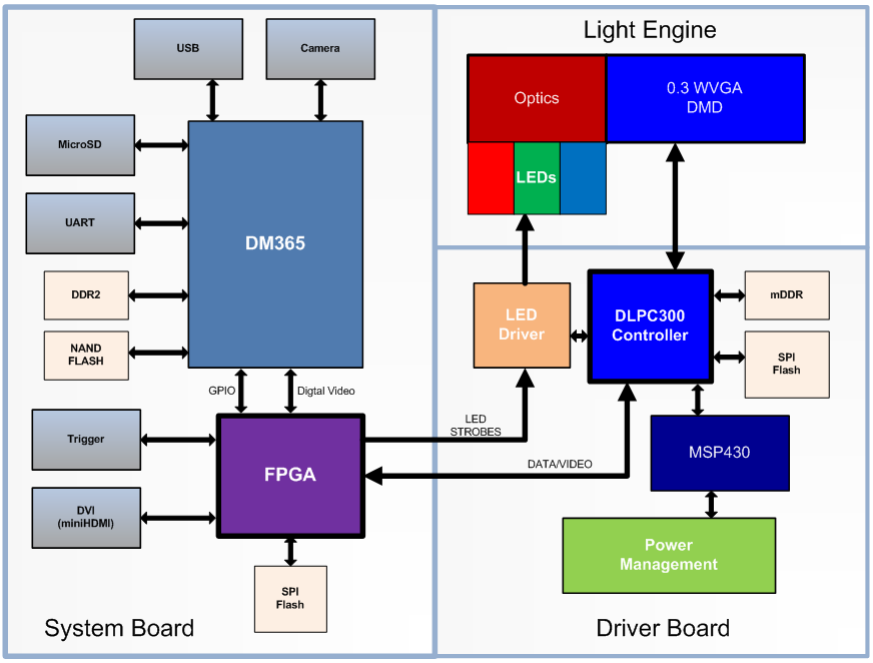

Figure 1-1. DLP LightCrafter Block Diagram

1.2.1 Light Engine

Young Optics, Inc. developed the DLP LightCrafter's light engine. The light engine consists of the following components:

- 0.3-inch WVGA DMD (DLP3000)
- OSRAM red LED (LE A Q9WN)
- OSRAM green LED (L CG H9RN)
- OSRAM blue LED (LE B Q9WN)
- Murata NTC thermistor (NCP15WF104F03RC)
- Optics with 1.66 throw ratio

The DLP3000 0.3-inch DMD contains 415872 mirrors arranged in a 608 by 684 with the diamond pattern geometry shown in Figure 1-2

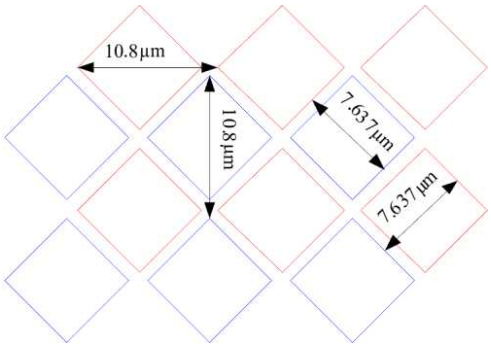

Figure 1-2. 0.3-inch DMD Pixel Geometry

The DMD is vertically mounted at the end of the light engine. The light engine, including the LEDs and not including the heat sinks, has a length of 39.3 mm, width of 41.6 mm, and height of 11 mm. Table 1-1 lists the specifications of the light engine:

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Table 1-1. DLP LightCrafter Light Engine Specifications

	MIN	TYP	MAX	UNIT
Brightness		10 at 0.6 W LED		lm
		25 at 1.85 W LED		
		30 at 2.25 W LED		
Brightness uniformity (JBMA)		70		%
ANSI contrast		43:1		
Full-on full-off contrast		685:1		
Color uniformity (CIE x)		0.03		
Color Uniformity (CIE y)		0.04		
F-number		2.2		
Throw ratio		1.66		
Offset		100		%
Focus range	364		2169	mm
Image diagonal size	10		60	inch
Focus stroke		1		mm

The MSP430 monitors the light engine's thermistor to shutdown the EVM if excessive heat is measured on the green LED. Passively cooled systems (no extra heat sinks or fans) have a thermal limit resulting in LED currents under 633 mA. Actively cooled systems (extra heat sink and fan) have a thermal limit resulting in LED currents under 1.5 A. See Table 2-1 for the corresponding LED current software settings.

1.2.2 Driver Board

Figure 1-3 shows the DLP LightCrafter's driver board block diagram.

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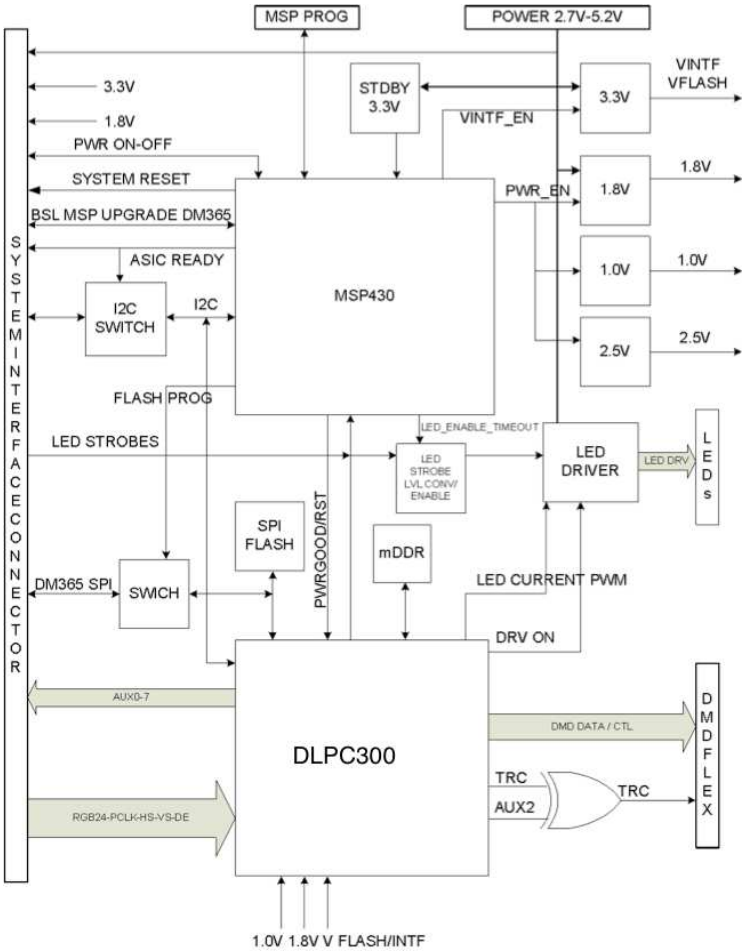

Figure 1-3. DLP LightCrafter Driver Board Block Diagram

The major components of the DLP LightCrafter's driver board are:

- DLP3000: 0.3-inch WVGA chipset DMD
- DLPC300: 0.3-inch WVGA chipset controller for DLP3000 with:
  - 2MB SPI flash that contains DLPC300 firmware
  - 32MB mDDR that buffers images for the DLP3000
- MSP430:
  - Controls power supply sequencing and system initialization
  - Shuts down system upon detection of low or high input voltage
  - Shuts down system if LED anode voltages exceed maximum limit
  - Measures thermistor and shuts down system when maximum temperature ratings are exceeded
- LED driver circuitry
- Power management:
  - TPS63020: buck-boost regulator for LED supplies
  - TPS63020: buck-boost regulator for 3.3-V supply
  - TPS62260: step-down converter for DLPC300 2.5-V supply
  - TPS62400: step-down converter for DLPC300 1.0-V and 1.8-V supply
  - TPS65120: 4-channel bias for DMD VRST and VBIAS supplies
  - TPS71501: LDO for DMD VOFS supply

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1.2.3 System Board

Figure 1-4 shows the DLP LightCrafter's system board.

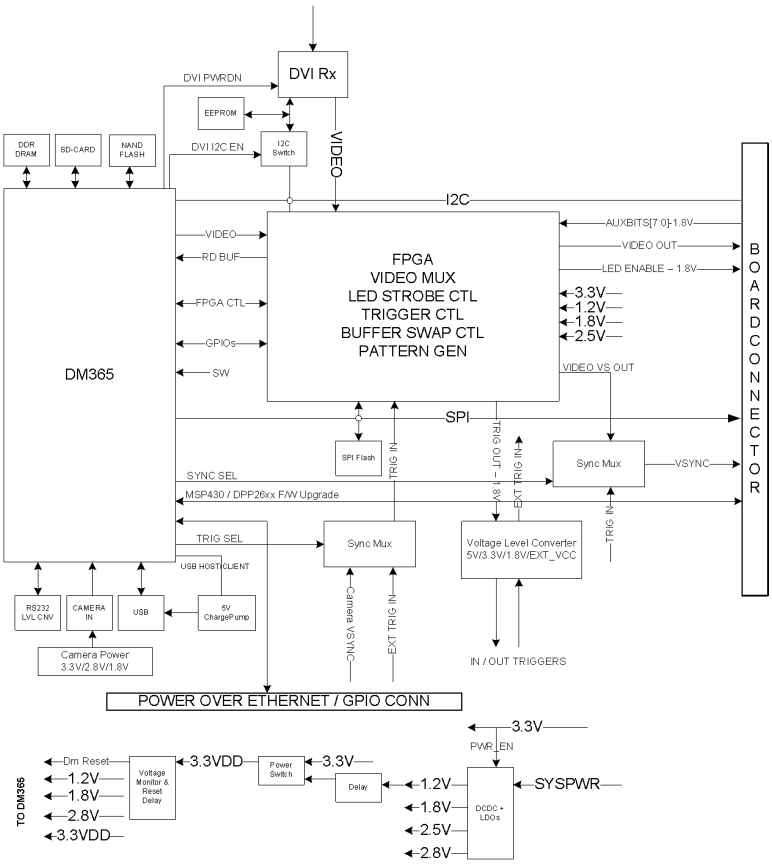

Figure 1-4. DLP LightCrafter System Board Block Diagram

The major components of the system board are:

- Altera Cyclone IV FPGA:
  - Controls video MUXing (external mini-HDMI or DM365)
  - Controls LEDs enables
  - Generates programmable camera triggers
  - Manages four internal buffers for fast pattern display
- DM365: Embedded Linux® main processor that controls camera interface, connectivity with PC, non-volatile storage (micro-SD and NAND flash), FPGA control, video output, and video buffer in DDR2.
  - 128MB DDR2 memory
  - Micro-SD connector
  - Mini-USB connector
  - UART mini-plug
- MiniHDMI connector (DVI-D compliant)
- Power management:
  - TPS650531: 2 step-down converter for FPGA's and DM365's 1.2-V and 1.8-V supplies with three LDOs for FPGA's 2.5-V supply and camera interface optional 2.8-V supply

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1.3 DLP LightCrafter Embedded Software Overview

1.3.1 DM365 Software

The DLP LightCrafter module software is based on TI's DVSDK platform running on the Digital Media System-on-Chip DM365. The DVSDK platform is a collection of royalty-free software components built upon Linux operating system and pretested by TI. The software components include Linux kernel, Linux filesystem, Linux product support package (PSP), application framework (APIs), codec libraries (MPEG4, H.264, MPEG2, G.711, JPEG), example programs, DSP Codegen, and CodeSourcery tool chain with IDE for cross-compiling and debugging target systems.

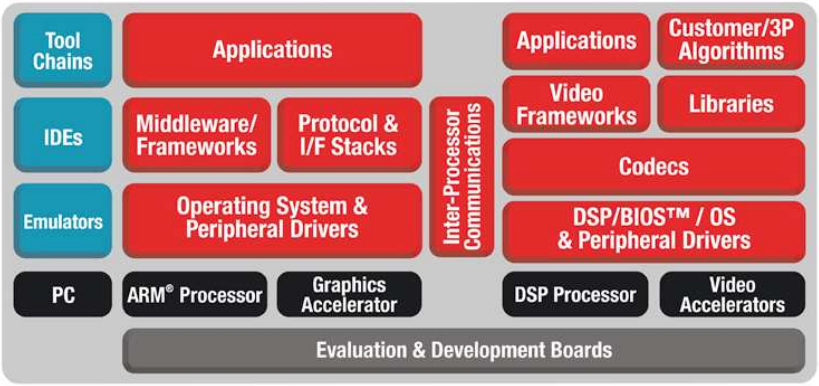

Figure 1-5. DM365 DVSDK Software Platform

Out of the box, the DLP LightCrafter boots from the on-board NAND flash. The DM365 acts as the main processor of the system and boots as an embedded Linux device. The Linux file system resides on the NAND or micro-SD card. Thus, the DLP LightCrafter does not require an NFS mount, nor a TFTP server to run. The embedded Linux system uses remote network drivers interface specification (RNDIS) to send packets through USB. DLP LightCrafter has a default IP address of 192.168.1.100.

1.3.1.1 Serial Communication

DLP LightCrafter's UART port serves as a console output of the embedded Linux device. The DM365 sends error messages through the UART and accepts root-level commands. A 2.5-mm stereo plug to female DB9 connector is needed to connect the DLP LightCrafter's UART port to a PC. For PCs with only USB ports, use a USB-to-serial RS232 adapter.

To view UART console messages, configure a terminal emulator with the following parameters:

- Baud: 115200
- Data bits: 8
- Stop bits: 1
- Parity: none
- Flow control: none

1.3.2 FPGA Overview

The FPGA expands the functionality of the DLP 0.3-inch WVGA chipset to enable the features of DLP LightCrafter. An important feature of DLP LightCrafter is the ability to display stored patterns at high frame rates. The FPGA provides the timing and signal management to implement a four-buffer rotation scheme, which enables a stored pattern capability of 4 × 24 = 96 binary patterns. Additional capabilities include:

- An external trigger input, which allows an external device to trigger stored patterns; configurable for polarity (positive or negative), delay, and duration (pulse width)
- An external trigger output, which provides the ability to synchronize an external camera with the display of patterns; configurable for polarity (positive or negative), delay, and duration (pulse width)

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- A timing generator, which implements the internal auto trigger for continuously repeated pattern display
- Control for the illumination LEDs; generates LED strobe signals with configurable delay and duration to set exposure; synchronized with the trigger
- A video data source input selector (MUX); sends the video data to the DLPC300 parallel input. Inputs are:
  - Video from the TFP401A DVI receiver
  - DM365 24-bit RGB (not bit identical with stored patterns)
  - DM365 YUV4:2:2 video converted to RGB888 (bit identical with stored patterns)
- Timing and signal management for a circular frame buffer

For more details, read the *DLP LightCrafter FPGA Overview* application note, DLPA042. Figure 1-6 shows the block diagram of the FPGA hardware.

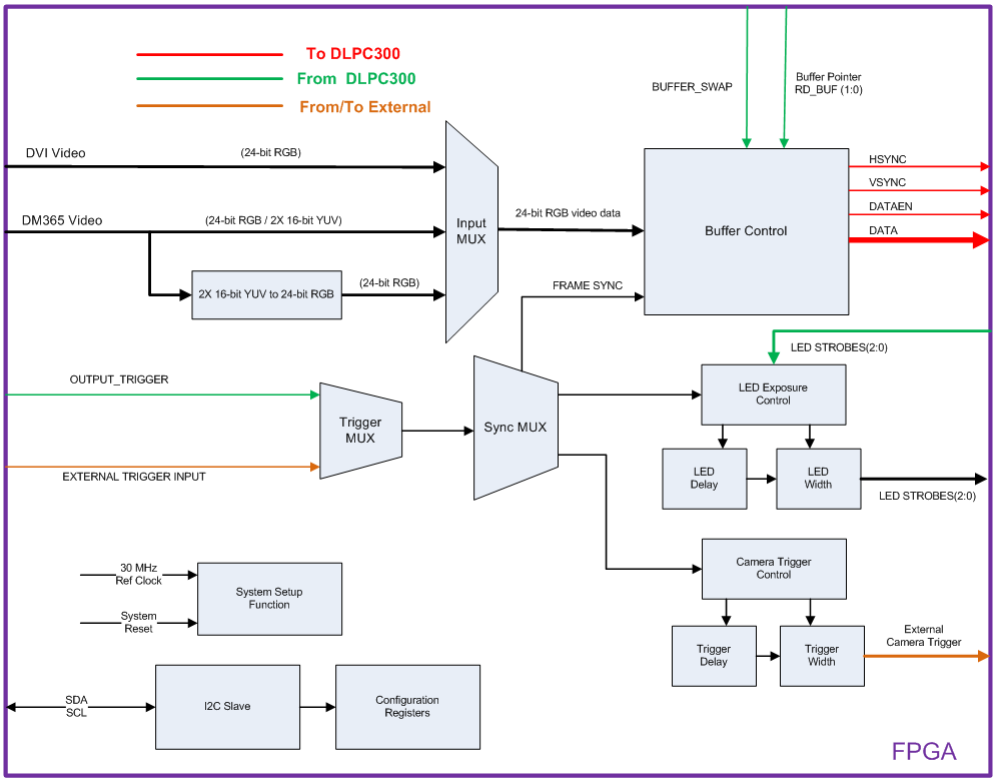

Figure 1-6. DLP LightCrafter FPGA Block Diagram

1.3.3 MSP430 Overview and Shutdown Protection Modes

The MSP430 controls the power sequencing, initializes the DLPC300, and provides safety shutdown protection modes for DLP LightCrafter. The MSP430 has three shutdown protection modes. The shutdown modes require that both the system power and USB cable be disconnected before a reboot is allowed. Each mode is displayed by blinking the red LED (D3) on the driver board at different rates. Table 1-2 describes the protection modes.

Table 1-2. DLP LightCrafter Protection Shutdown Modes

Shutdown Mode Description	D3 On Time (s)	D3 Off Time (s)
System voltage less than 3.8 V or greater than 5.2 V	5	0.5
LED anode voltage above 5.8 V	5	5
Light engine thermistor above 70°C	1.5	1

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1.4 Other Items Needed for Operation

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

- Power supply: provides 5-V to DLP LightCrafter module
  - Output: 5-V [1] with 2- to 3-A current rating
  - Inner plug diameter: 0.7 mm
  - Outer diameter: 2.35 mm
  - Female shaft length: 9.5 mm
  - Positive center
- USB cable: A to mini-B
- RS232 cable with 2.5-mm stereo plug

1.5 DLP LightCrafter Connections

DLP LightCrafter offers the following connectivity options:

- Power socket: connector that matches power supply described in section Section 1.4
- Mini-HDMI: supports external video input with 608 × 684 resolution at 60 Hz
- Micro-SD: tested to support up to 4GB, class 10, high-capacity cards for DM365 software and local data storage
- Mini USB: interfaces to PC as a slave device. A program running on the PC issues commands to the DLP LightCrafter module
- Camera connector: 28-pin connector using ITU-R BT.656 compatible camera interface. The camera interface supports up to 12-bit data.
- Trigger connector: supports external or internally generated triggers for camera capture
- Serial flash programming connectors:
  - Driver board: programs the MSP430 flash and DLPC300 serial flash
  - System board: programs the FPGA serial flash
- UART mini-plug: allows serial messages with the following RS-232 compatible serial configuration:
  - 2.5-mm stereo plug: tip-RX, ring-TX, ground-GND
  - Bits per second: 115200
  - Data bits: 8
  - Parity: none
  - Stops bits: 1
  - Flow control: none

Figure 1-7 shows the connectors and their respective locations.

[1] If the power supply voltage drops below 3.8 V or above 5.2 V, the system may enter a shutdown mode as mentioned in table Table 1-2

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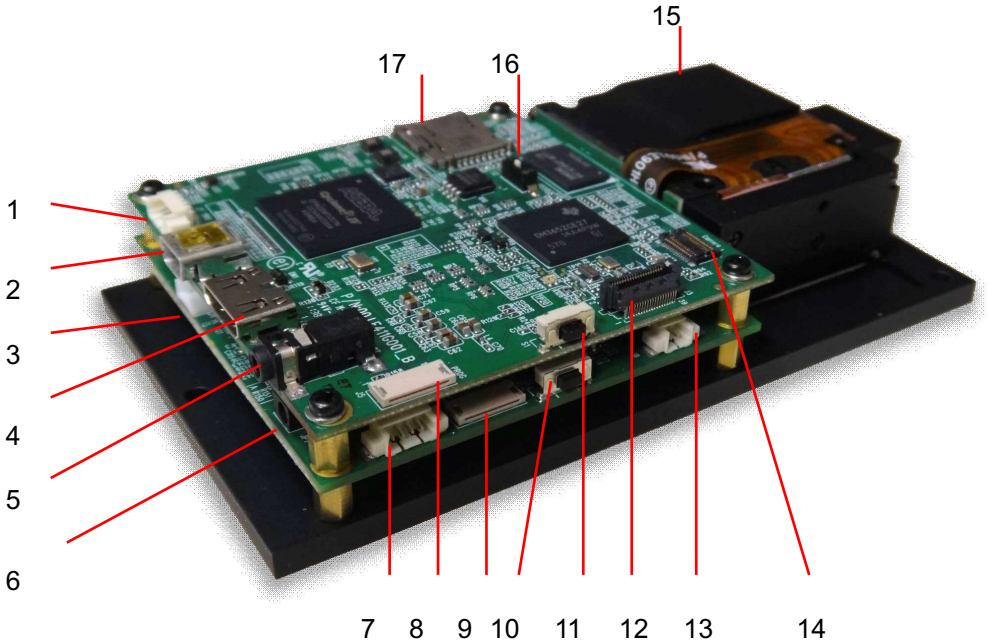

1. Trigger input and output
2. Mini USB
3. Power connector
4. Mini HDMI
5. UART
6. Power socket
7. I^2C
8. FPGA SPI flash programming interface
9. MSP430 or DLPC300 flash programming interface
10. On or off button – Do not turn off while the Linux system is booting
11. Input selection button (DM365, internal test pattern, or HDMI input)
12. Ethernet PHY
13. Fan
14. Camera
15. Focus control
16. Boot mode selection switch
17. Micro-SD card

Figure 1-7. DLP LightCrafter Connector Locations

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1.6 DLP LightCrafter's Dimensions

The DLP LightCrafter optical engine is mounted on top of a thermal plate to provide passive cooling to the module. The DLP3000, 0.3-inch DMD, is vertically mounted at the end of the optical engine and attached with a connector to the driver board. The system board is mounted on top of the driver board. This module has dimensions of 116.5-mm long, 65-mm wide, and 23-mm tall. Figure 1-8 shows the DLP LightCrafter dimensions.

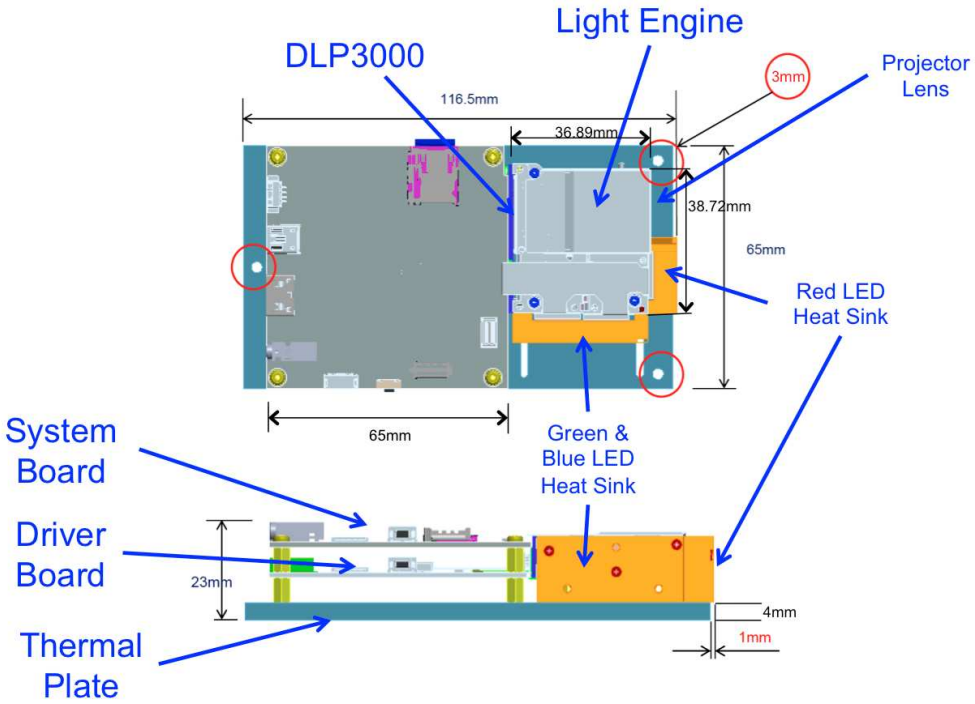

Figure 1-8. DLP LightCrafter Module Dimensions

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Operating the DLP LightCrafter

This chapter describes installing the graphical user interface (GUI), controlling the DLP LightCrafter module using the GUI, and upgrading the firmware on the EVM. All instructions relating to the GUI in this document refer to the latest DLP LightCrafter GUI v5.0.

2.1 Installing the GUI

DLP LightCrafter includes a QT-based GUI to control the module through USB. QT is a Nokia cross-platform application and user interface framework with open source and commercial licenses. To install the DLP LightCrafter GUI, follow these steps.

1. Download the most recent version of the DLP LightCrafter software bundle from www.ti.com/tool/dlplightcrafter.
   - Linux users also need to install the latest QT version 5 library. Available from http://qt-project.org/downloads. After the QT library is installed, the user must create a file in the "etc/ld.so.conf.d" directory so that the GUI coorrectly accesses the QT library. Create a file called "Qt5.conf" in the "etc/ld.so.conf.d" directory and enter the location of the QT5 library directory (for example, "<QtInstall_dir>/5.1.1/gcc/lib"). Verify the actual directory path of the "lib" directory in the installed QT5 library. After the file has been saved, run "ldconfig" in the terminal.
2. Extract the files from the downloaded zip file.
3. Run the DLP LightCrafter software bundle installer.
   - Linux users may need to right-click on the installer file and set a property to "Allow executing file as program" so the installer executes correctly.
   - Linux and Mac installers may attempt to install the software bundle to the root directory, which for some users may not be accessible. Choosing a different installation directory, such as the user's home or documents folder should allow the installation to run properly.
4. From the GUI directory of the installed software, double click on the LightCrafterGUI application to run the GUI. By default the GUI is installed in one of the following directories:
   - Windows® XP and Windows 7: "C:\Texas Instruments-DLP\DLPLCRSoftwareBundle-3.0\LightCrafterGUI-v5.0-Windows"
   - Linux: ".../Texas Instruments-DLP/DLPLCRSoftwareBundle-3.0/LightCrafterGUI-v5.0-Linux"
     - Linux users may need to right-click on the GUI executable file and set a property to "Allow executing file as program" so the GUI operates correctly.
   - Mac: ".../Texas Instruments-DLP/DLPLCRSoftwareBundle-3.0/LightCrafterGUI-v5.0-Mac"

2.2 Connecting to a PC

The DLP LightCrafter uses remote network drivers interface specification (RNDIS) to send packets through USB. Read *Section 2.2.1* or *Section 2.2.2* to install the RNDIS drivers on Windows systems. The drivers are already installed for Linux and Mac® computers. Some Linux systems need to have USB networking enabled.

After the RNDIS driver has been installed on the PC, follow these steps to connect the DLP LightCrafter. By default, DLP LightCrafter's default IP address is 192.168.1.100, but this can be changed to allow for multiple DLP LightCrafter's to connect to one computer. Read *Section 2.2.6* for more details. To connect DLP LightCrafter to a PC, follow these steps:

1. Connect the DLP LightCrafter to the PC using a mini-USB cable.

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2. Turn on DLP LightCrafter using the on-off switch. A new network using the RNDIS driver should initialize.
   - The network interface on Windows systems may take a couple minutes to initialize. Read *Section 2.2.4* to speed up the initialization.
3. Open the DLP LightCrafter GUI.
4. Click the Connect button. See Figure 2-1.
   - The GUI connects to the IP address in the "Current IP Address" textbox from the "Connections" tab. Read *Section 2.2.5* steps 7 and 8 for more details.
   - After connecting, the GUI displays DLP LightCrafter's firmware versions. Select the correct tab, according to the display mode, to update the GUI's tab settings to match the EVM's settings.

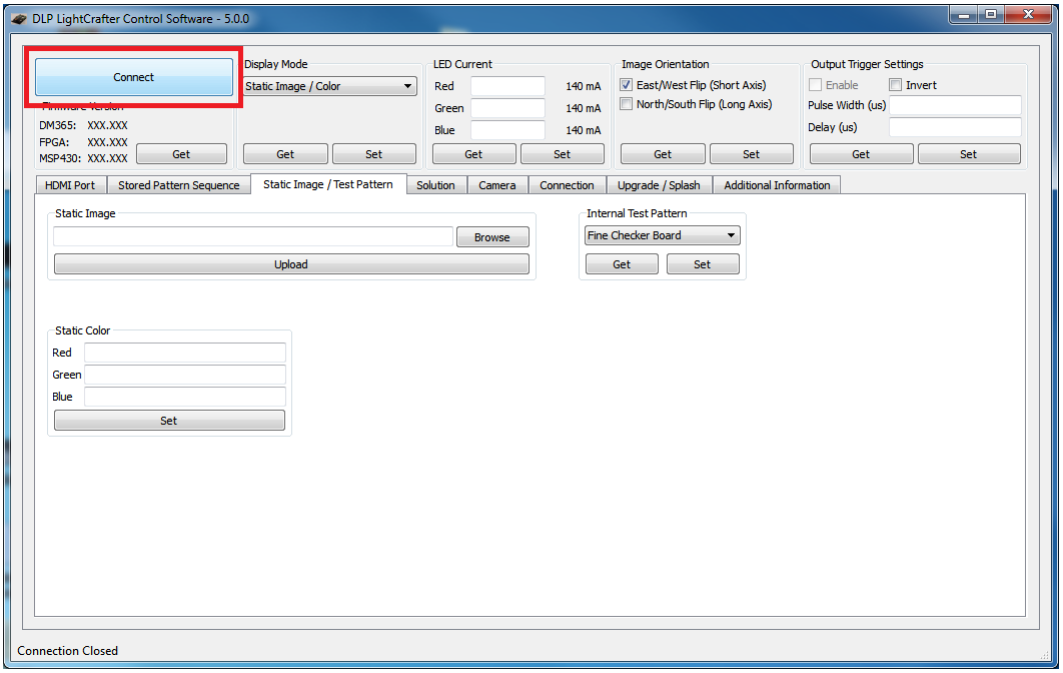

Figure 2-1. DLP LightCrafter GUI Connect Button

5. Click the Disconnect button before disconnecting the USB cable between DLP LightCrafter and the computer. See Figure 2-2.
   - The Connect button changes to the Disconnect button after a DLP LightCrafter connects.
   - Unplugging the USB cable before disconnecting can cause problems when trying to reconnect to the DLP LightCrafter if the device has not been shutdown.

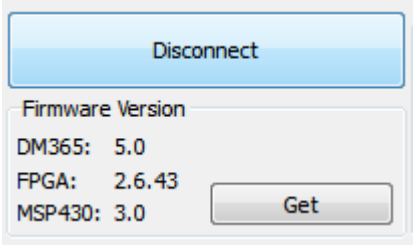

Figure 2-2. DLP LightCrafter GUI Disconnect Button

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2.2.1 Installing the RNDIS Driver on Windows XP

The first time DLP LightCrafter connects to Windows XP, a system popup window shows the new "RNDIS/Ethernet Gadget" hardware device. Windows XP Service Pack 2 or greater includes the RNDIS drivers, so these drivers should be found by the OS. Follow these steps to install the "RNDIS/Ethernet Gadget" driver to enable USB communication with the EVM:

1. When the "Found New Hardware" dialog appears, as shown in Figure 2-3 and Figure 2-4, allow Windows Update to search for the software.
2. Select “Install the software automatically (Recommended)” and click "Next." See Figure 2-4.
   - The computer must have an active internet connection to download the driver.

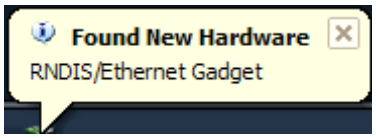

Figure 2-3. Windows XP Found New Hardware Popup

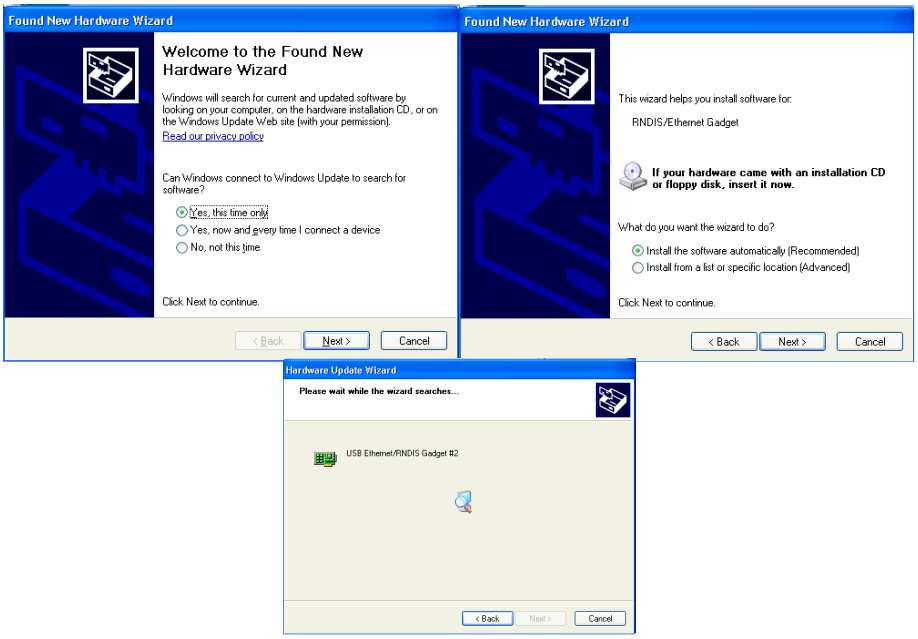

Figure 2-4. Windows XP Found New Hardware Wizard

2.2.2 Installing the RNDIS Driver on Windows 7

The first time DLP LightCrafter is connected on Windows 7 systems a popup window appears stating that a new hardware device called a "RNDIS/Ethernet Gadget" was found. Follow these steps to install the "RNDIS/Ethernet Gadget" driver to enable USB communication with the EVM:

1. The "Driver Software Installation" dialog should appear. Windows 7 will try to automatically download the driver and fail. A message indicating that the “device driver software was not successfully installed" is displayed. See Figure 2-5.

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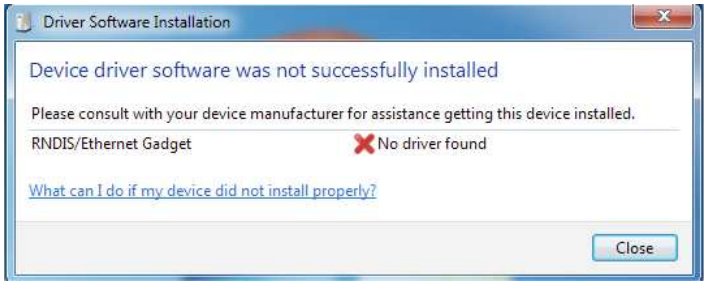

Figure 2-5. Windows 7 Driver Software Installation Window

2. Right-click on “My Computer” and open the Device Manager.
3. Expand Other Devices. Right-click on “RNDIS/Ethernet Gadget” and select “Update Driver Software.” See Figure 2-6.

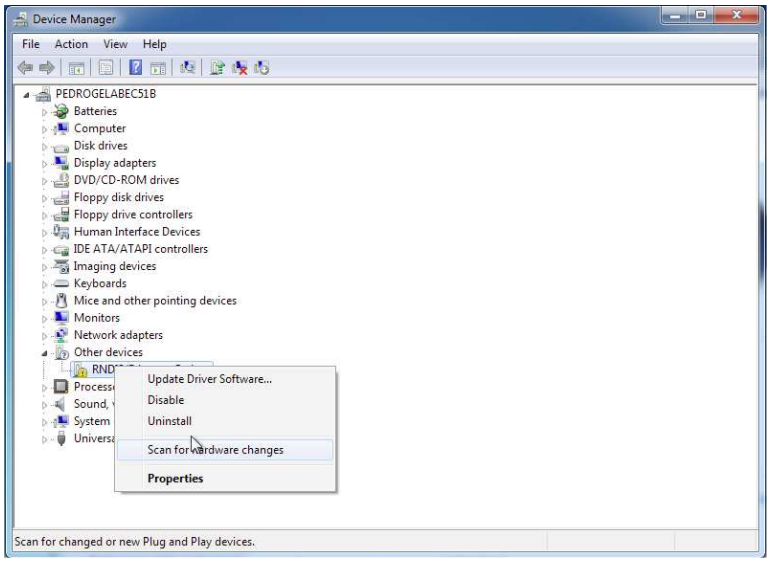

Figure 2-6. Windows 7 Device Manager Window

4. Select “Browse my computer for driver software” from the “Update Driver Software” window. See Figure 2-7.

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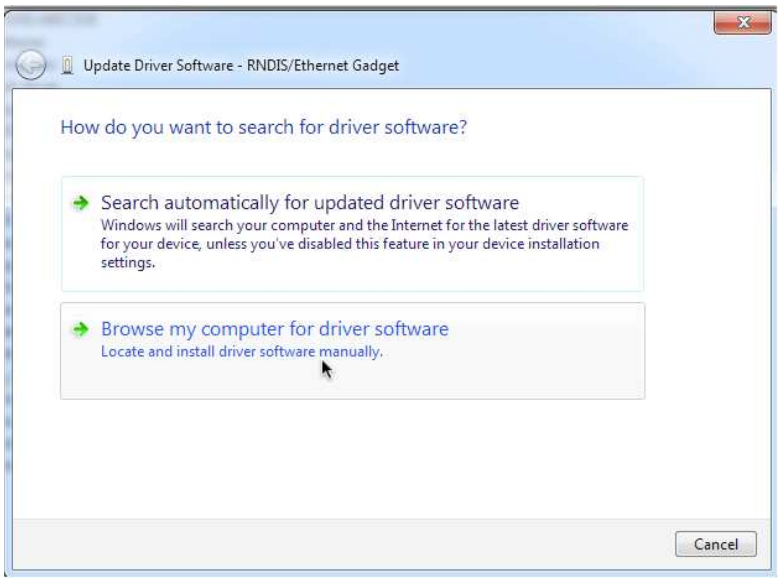

Figure 2-7. Windows 7 Update Driver Software Search or Browse Window

5. On the next dialog, select “Let me pick from a list of device drivers on my computer.”
6. Select "Network Adapter." See Figure 2-8.

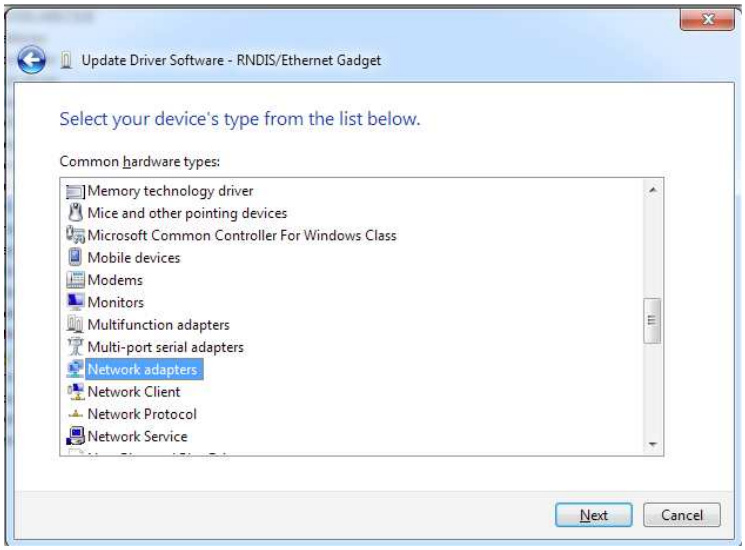

Figure 2-8. Windows 7 Update Driver Software Select Device Window

7. Select "Microsoft Corporation" as the manufacturer and “Remote NDIS Compatible Device” as the network adapter. Click "Next." See Figure 2-9.

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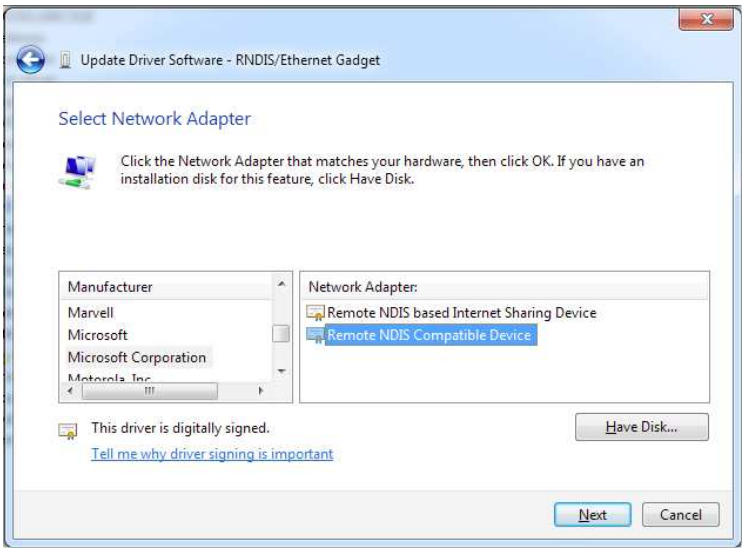

Figure 2-9. Windows 7 Update Driver Software Select Network Driver Window

8. Click "Close" after the software updates. See Figure 2-10.

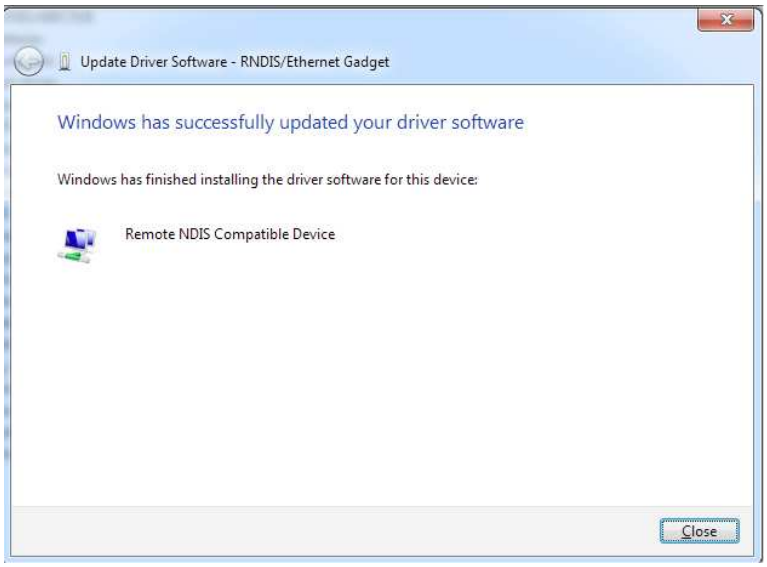

Figure 2-10. Windows 7 Update Driver Software Successfully Updated Window

2.2.3 Enabling the RNDIS Driver on Linux

DLP LightCrafter connects to Linux systems as a Linux-USB Ethernet/RNDIS device. Some systems require USB networking support to be manually enabled. To enable USB networking follow these steps:

1. Open a command terminal.
2. Open the "/etc/network/interfaces" file in superuser mode. See Figure 2-11.
   - For example, "sudo gedit /etc/network/interfaces"
3. Add "iface usb0 inet dhcp" to the file. See Figure 2-11.

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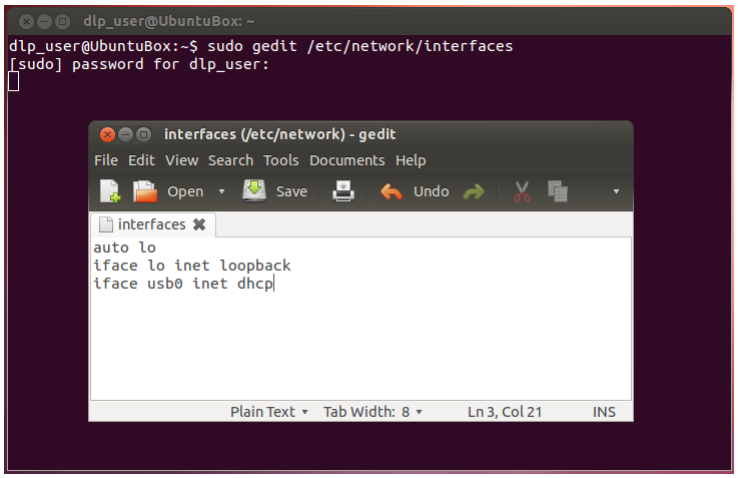

Figure 2-11. Ubuntu® Command Terminal and "interfaces" File

4. Save the file.
5. Reboot the Linux system and run "ifconfig." See Figure 2-12.
   - If "usb0" is not present, continue to step 6.

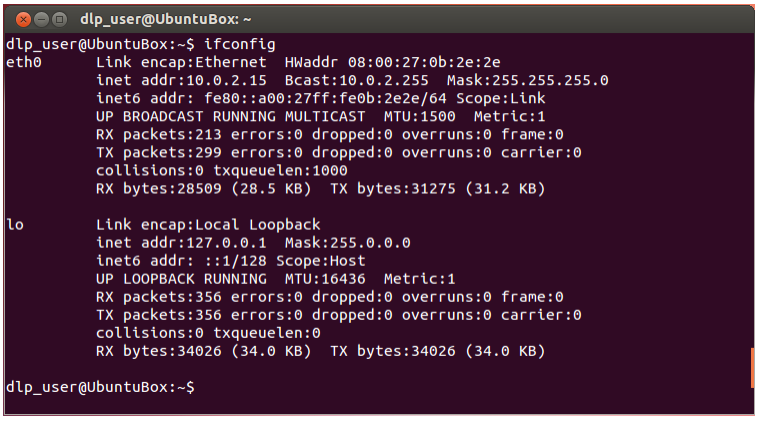

Figure 2-12. Ubuntu Command Terminal "ifconfig" Result Before USB Setup

6. Setup usb0 with IP address. See Figure 2-13.
   - For example, "sudo ifconfig usb0 192.168.1.99 up"
   - Choose an IP address different than the address of the LightCrafter.
7. Check that usb0 was properly assigned an IP address using "ifconfig." See Figure 2-13.

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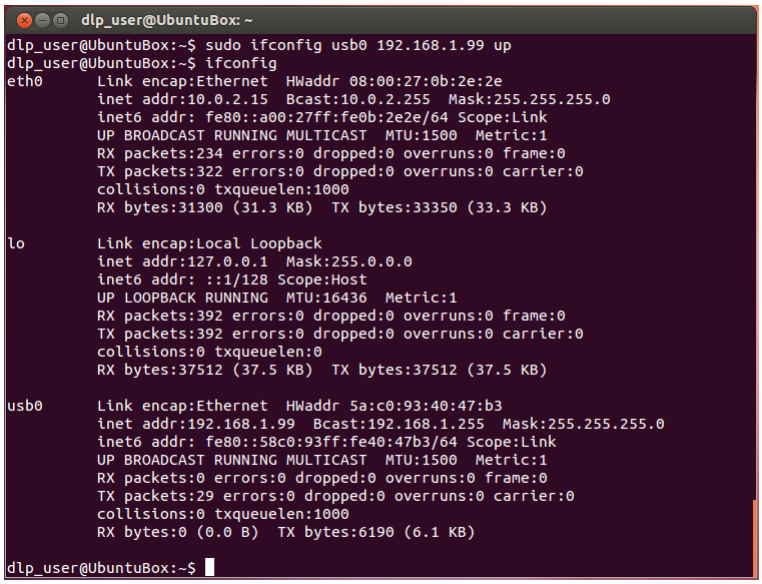

Figure 2-13. Ubuntu Command Terminal "ifconfig" Result After USB Setup

2.2.4 Fixing the USB Start-Up Delay in Windows

When DLP LightCrafter is first connected to a Windows system, the local area connection created automatically obtains an IP address. This "Identifying..." process for the Local Area Connection can take over a minute on some systems. To decrease the time required for DLP LightCrafter to connect, the local area network assigned an IP address allowing the computer to connect to the EVM within seconds after fully booting. Follow these steps to assign an IP address for the local area connection:

1. Open the Control Panel and type "Network Connections" into the search bar.
2. Select "View Network Connections." See Figure 2-14.

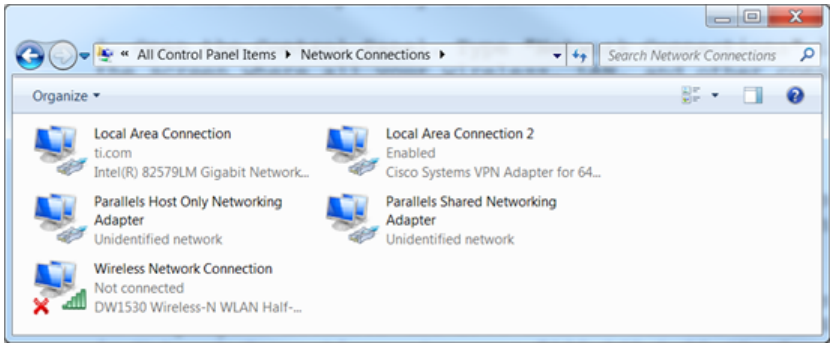

Figure 2-14. Windows 7 Network Connections Window

3. Connect DLP LightCrafter to the computer through a mini-USB cable.
4. Power on DLP LightCrafter. While it boots, a new local area connection in your Network Connections appears.
5. Wait until the LAN connection stops "Identifying" or "Acquiring" a network address. See Figure 2-15.

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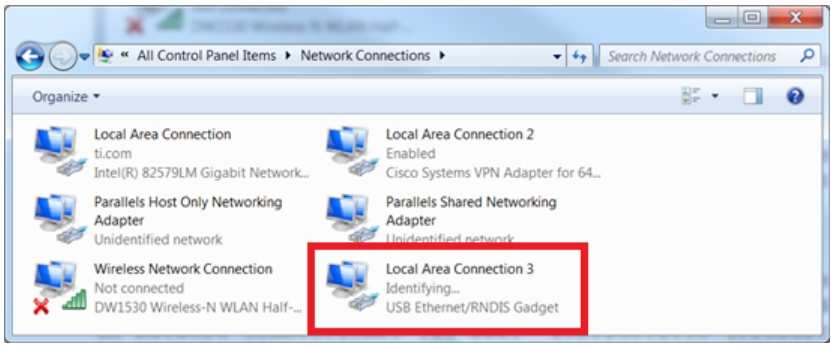

Figure 2-15. Windows 7 Network Connections Identifying Local Area Connection

6. Open a cmd terminal and run "ipconfig /all"
7. A list of all connections will be displayed. Find the IPv4 address and Subnet Mask of DLP LightCrafter's local area connection. See Figure 2-16.

Figure 2-16. Windows 7 Command Window Local Area Connection IPv4 Address

8. From the Network Connections window, right-click on DLP LightCrafter's local area connection and click "Properties".
9. In the box "This connection uses the following items" under the Networking tab, look for “Internet Protocol Version 4”. Highlight the item by clicking on it, and then click “Properties” underneath the box. See Figure 2-17.

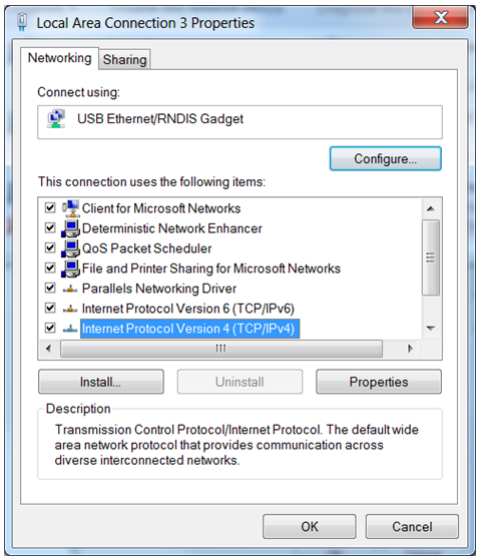

Figure 2-17. Windows 7 Local Area Connection Properties

10. Choose "Use the following IP address".
11. Enter the IPv4 address and subnet mask found from step 7. See Figure 2-18.
    - Please note that each connected device and USB port requires a unique IP address for its local area connection.

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- If you are having issues with your connection to the LightCrafter or the internet, set the 'Default gateway' to the LightCrafter's IP address. By default this is 192.168.1.100, however it can be changed as described in section Section 2.2.5

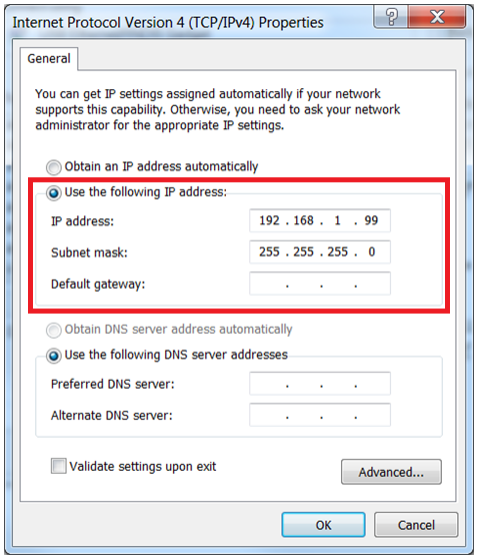

Figure 2-18. Windows 7 Local Area Connection TCP/IPv4 Properties

12. Click OK to exit the IPv4 properties
13. Click OK to exit the LAN connection properties.

2.2.5 Changing the DLP LightCrafter's IP Address

To change DLP LightCrafter's IP address, follow these steps:

1. Connect DLP LightCrafter GUI to EVM.
2. Select the "Connections" tab. See Figure 2-19.

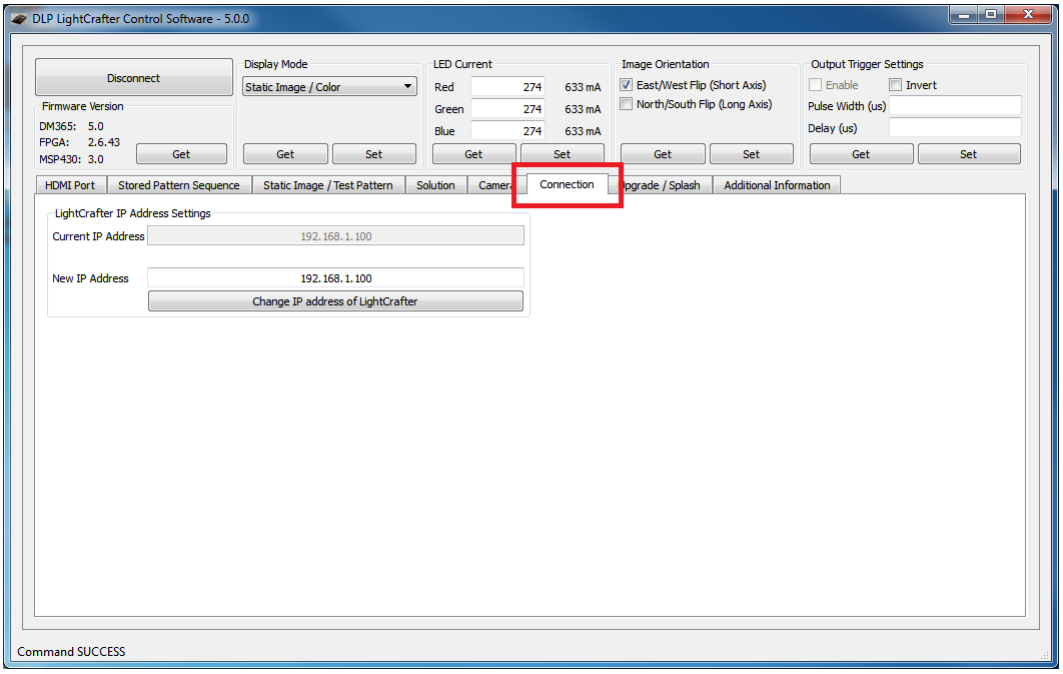

Figure 2-19. DLP LightCrafter GUI Connection Tab

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3. Change the last three digits of the IP address in the "New IP Address" textbox. See Figure 2-20.
   - For example: Change "192.168.1.100" to "192.168.1.106"
   - TI recommends to use even IP addresses to prevent IP address conflicts between the computer's local area connection and DLP LightCrafter.

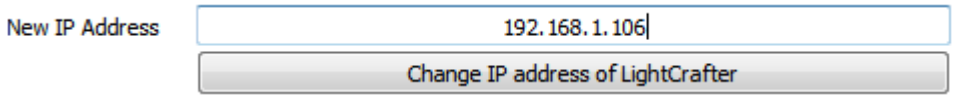

Figure 2-20. DLP LightCrafter GUI Connection New IP Address Textbox

4. Click the "Change IP address of LightCrafter" button.
5. A popup window, as shown in Figure 2-21, will ask "Do you want to change the IP of the LightCrafter?" Click "Yes."

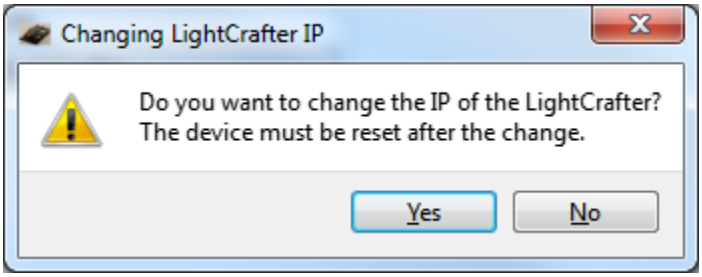

Figure 2-21. DLP LightCrafter GUI Changing IP Popup

6. Restart the EVM using the on-off button on the driver board, by powering the device off and back on.
   - The GUI disconnects from DLP LightCrafter automatically.
   - The "Current IP Address" textbox does not update until the EVM is reconnected.
7. After DLP LightCrafter has restarted and the network has initialized, select the "Connection" tab.
8. Type DLP LightCrafter's new IP address into the "Current IP Address" textbox. See Figure 2-22.
   - This setting cannot be modified while the GUI is connected to an EVM.

Figure 2-22. DLP LightCrafter GUI Connection Current IP Address Textbox

9. Click the Connect button.

2.2.6 Connecting Multiple DLP LightCrafter's to One PC

By changing DLP LightCrafter's IP address, it is possible to control multiple EVMs from a single computer. Follow these steps to control multiple DLP LightCrafter's from a single computer:

1. Connect one DLP LightCrafter to the computer with a USB cable.
2. Follow the steps in *Section 2.2.5* to set a unique IP addresses for the connected EVM.
3. Disconnect and turn off the EVM.
4. Repeat steps 1 to 3 for each DLP LightCrafter.
5. After all DLP LightCrafter's have unique IP addresses, start an instance of the DLP LightCrafter GUI for each EVM
   - For example: If three DLP LightCrafters will be connected, there should be three GUI windows running.
6. For each open GUI window, follow steps 7 to 9 in *Section 2.2.5* to connect each DLP LightCrafter, using their unique IP address, to the open GUI windows.

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2.3 Selecting the Display Mode

The DLP LightCrafter has four display modes: Static Image/Color, Test Patterns, HDMI Port, and Stored Pattern Sequence. To upload static 24-bit RGB images or project a single color read *Section 2.9*. To use the internally generated test patterns, read *Section 2.10*. To stream 24-bit RGB video through the HDMI port read *Section 2.7*. To create a pattern sequence using external patterns from the HDMI port, read *Section 2.8.2*. To create a pattern sequence using stored patterns, read Section 2.8.1. See *Figure 2-23*.

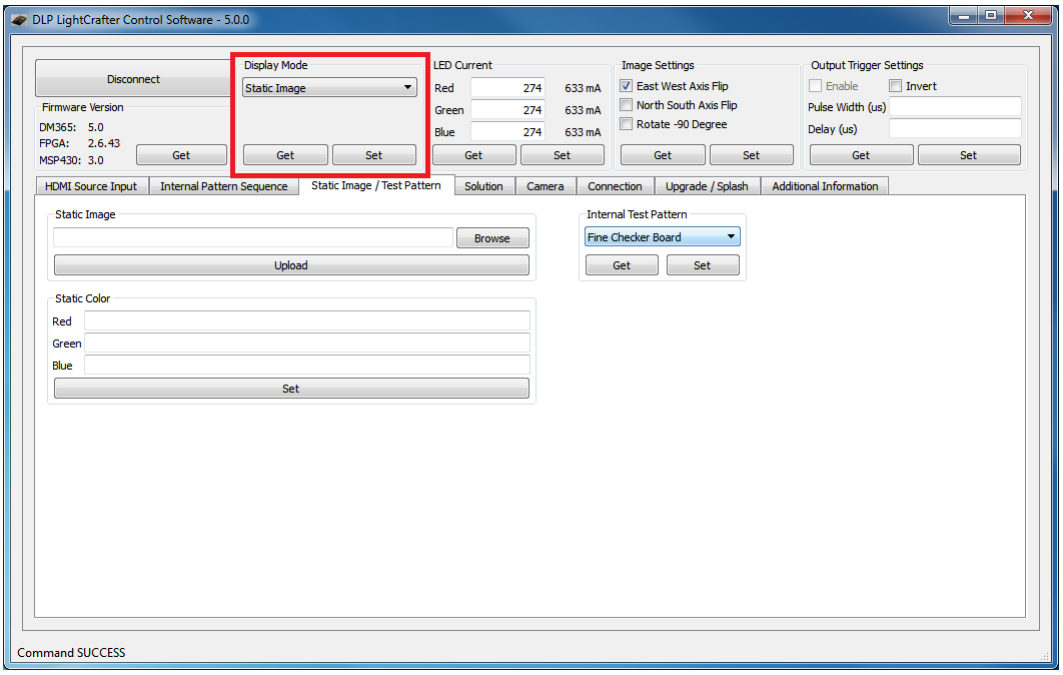

Figure 2-23. DLP LightCrafter GUI Display Mode Setting

To change the display mode, follow these steps:

1. Click and select the desired display mode from the dropdown options as shown in Figure 2-24.

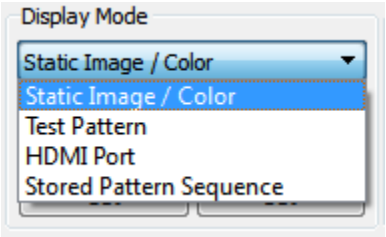

Figure 2-24. DLP LightCrafter GUI Display Mode Options

2. Click the Set button as shown in Figure 2-25.
   - The GUI automatically changes to the correct tab and updates the GUI settings in that tab to match the EVM's settings if the display mode is properly set.
   - The resolution, active pixels, and active lines are reset to their default value if the display mode changes from "HDMI Port" to "Stored Pattern Sequence".
   - When the display mode changes, the "Start Vector" and "Num of Vectors" reset to 0.

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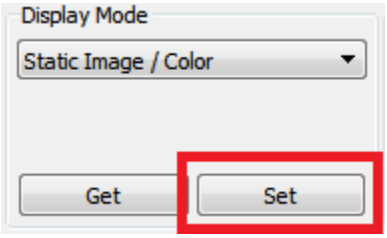

Figure 2-25. DLP LightCrafter GUI Display Mode Set Button

3. To retrieve the EVM's display mode, click the "Get" button.
   - The GUI automatically changes to the correct tab and updates the GUI settings in that tab to match the EVM's settings.

2.4 Setting the LED Current

The DLP LightCrafter uses current drivers to individually control the current through each LED using an integer current value. The LED current is computed as follows:

$$\text{LED Current (mA)} = 1.8 \times (\text{LED Current Value}) + 140 \quad (1)$$

When at room temperature, the maximum value allowed is dependent on the cooling system of the DLP LightCrafter. The passively cooled systems of the DLP LightCrafter (no extra heat sinks or fans) have a thermal limit resulting in LED currents under 633 mA. DLP LightCrafter actively-cooled systems (extra heat sink and fan) have a thermal limit resulting in LED currents under 1.5 A. Table 2-1 summarizes these constraints. Figure 2-26 shows the "LED Current" settings in the GUI.

Table 2-1. LED Current Settings

DLP LightCrafter Cooling System	LED Current Value		Led Current
	MIN	MAX	MAX
Passively cooled	1	274	633 mA
Actively cooled	1	758	1.5 A

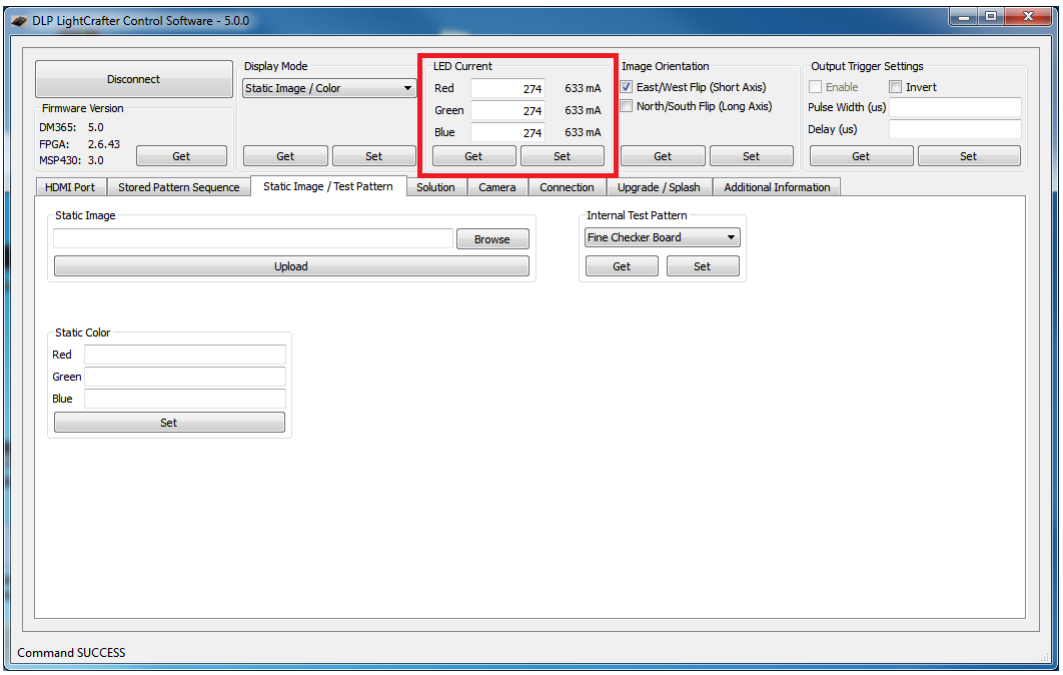

Figure 2-26. DLP LightCrafter GUI LED Current Settings

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To change the DLP LightCrafter LED current follow these steps:

1. Type the LED current value into the corresponding LED's textbox. The GUI automatically calculates and displays the LED current in mA.
   - If the value is above 274, a note is added to the LED current title to inform the user that active cooling is needed. See Figure 2-27.

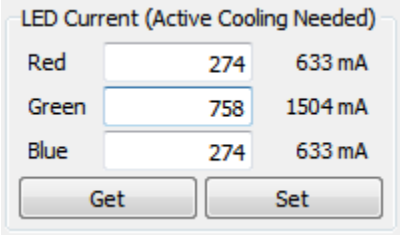

Figure 2-27. DLP LightCrafter GUI LED Current Setting Active Cooling Needed

   - If the value is above 758, the value turns red and a note is added to the LED current title to inform the user that this is not a recommended setting. See Figure 2-28.

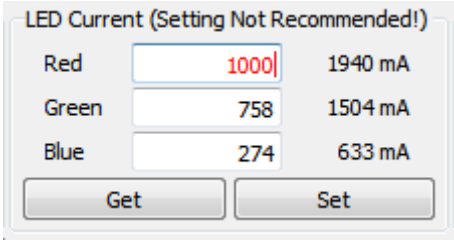

Figure 2-28. DLP LightCrafter GUI LED Current Setting Not Recommended

2. Click the Set button as shown in Figure 2-29.

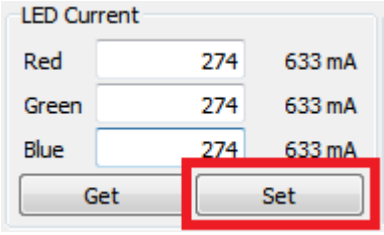

Figure 2-29. DLP LightCrafter GUI LED Current Setting Set Button

3. To retrieve the EVM's current LED current value, click the Get button.

2.5 Controlling Image Orientation

The image orientation controls the long- and short-axis flips to support front, rear, table, and ceiling-mounted projection. The image orientation takes place after the Set button has been clicked. Figure 2-30 shows the "Image Orientation" settings in the GUI.

- East/west flip (short-axis): If checked, the image is flipped along the east/west axis of the projected image. Normal table front projection has this setting checked (otherwise, the image is flipped horizontally).
- North/south flip (long-axis): If checked, the image is flipped along the north/south axis of the projected image. Normal table front projection has this setting unchecked (otherwise, the image is flipped vertically).

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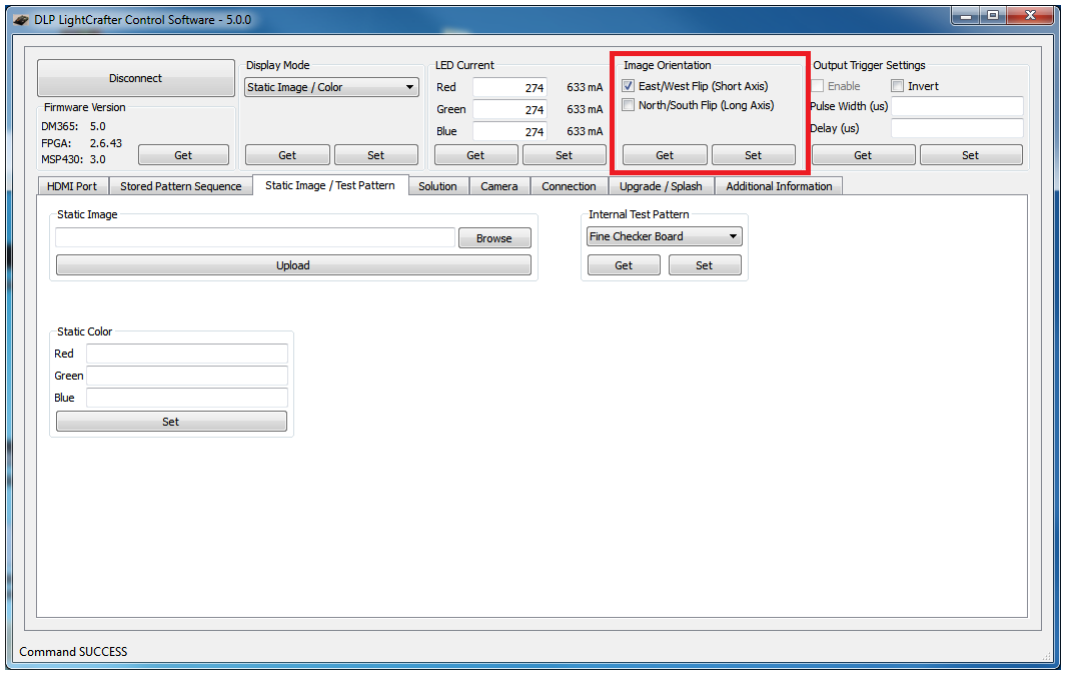

Figure 2-30. DLP LightCrafter GUI Image Orientation Settings

2.6 Triggering External Peripherals (Camera and so Forth)

The DLP LightCrafter features a trigger output on connecter J7 to allow cameras and other peripherals to be in sync with the EVM. The trigger output is an open-drain type with a 10-kΩ internal pullup resistor. This works well with cameras accepting a standard TTL level trigger input. Some cameras with global trigger capability require a minor hardware change on the DLP LightCrafter system board in order to function correctly. For more information, read *Using the DLP® LightCrafter™ to Trigger CCD Cameras from The Image Source®*, DLPA032. Figure 2-31 shows the "Output Trigger Settings" in the GUI.

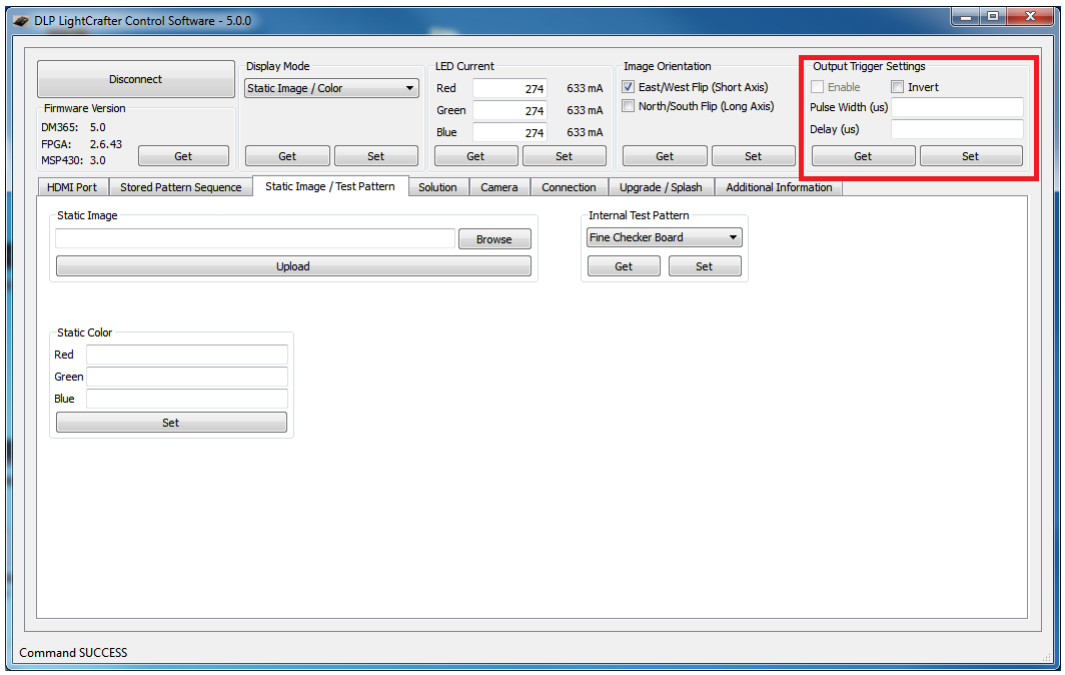

Figure 2-31. DLP LightCrafter GUI Output Trigger Settings

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To setup the output trigger, follow these steps:

1. Check the "Enable" checkbox in the Output Trigger Settings as shown in Figure 2-32.
   - The output trigger can only be enabled if the EVM is in either "Stored Pattern Sequence" mode or "External Streaming Pattern Sequence" while in "HDMI Port" mode.

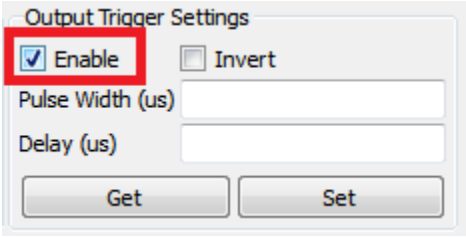

Figure 2-32. DLP LightCrafter GUI Output Trigger Enable Checkbox

2. If an active-low trigger output is desired, check the "Invert" checkbox. If an active high trigger output is desired, do not check "Invert"
3. Enter the pulse width and delay in microseconds
   - Pulse width: width of trigger output pulse in microseconds
   - Delay: number of microseconds pulse is delayed after pattern exposure begins
4. Click "Set" as shown in Figure 2-33.

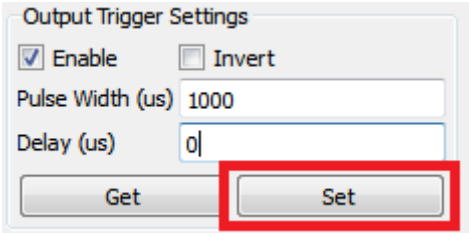

Figure 2-33. DLP LightCrafter GUI Output Trigger Set Button

5. To retrieve DLP LightCrafter's current output trigger settings, click the Get button

2.7 Streaming 24-Bit RGB Video from the HDMI Port

DLP LightCrafter can operate as a DVI-D compliant projector with its mini-HDMI connector. By default, the EVM has the 608 × 684 EDID software installed, and supports resolutions listed in Table 2-2.

Table 2-2. Supported Resolutions for Video Input

240 x 320	640 x 480	480 x 852	864 x 480
320 x 240	480 x 720	852 x 480	720 x 240
240 x 427	720 x 480	480 x 853	720 x 288
427 x 240	480 x 752	853 x 480	360 x 640
430 x 640	752 x 480	480 x 853	640 x 360
640 x 430	480 x 800	854 x 480	854 x 480
480 x 640	800 x 480	480 x 854	608 x 684

To stream 24-bit RGB video, follow these steps:

1. Connect an active HDMI source to the mini HDMI connector. [1]
2. Set Display Mode to “HDMI Port.”
3. Select "RGB Video Streaming (24 bits per pixel)" as shown in Figure 2-34.

[1] The video input port is DVI-D compliant, but not HDMI compliant.

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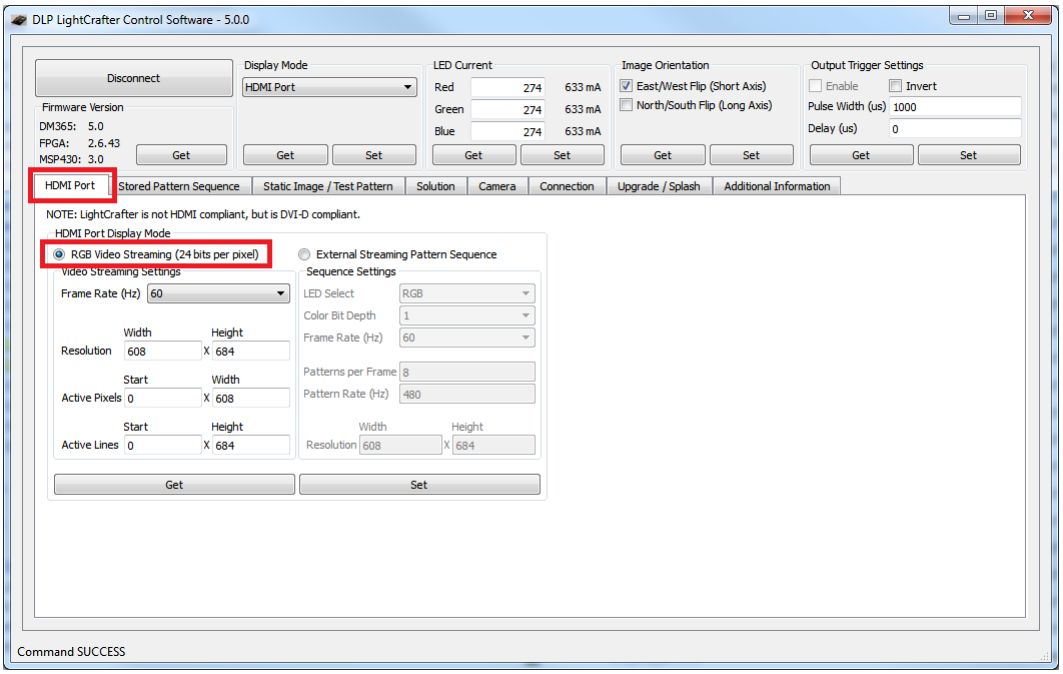

Figure 2-34. DLP LightCrafter GUI RGB Video Streaming Selected on HDMI Port Tab

4. Select the frame rate.
5. Enter one of the resolutions listed in Table 2-2.
6. If the full frame is desired:
   - Set Active Pixels Start to 0
   - Set Active Pixels Width to the resolution width entered in step 5
   - Set Active Lines Start to 0
   - Set Active Lines Height to the resolution height entered in step 5
7. Click the Set button as shown in Figure 2-35.

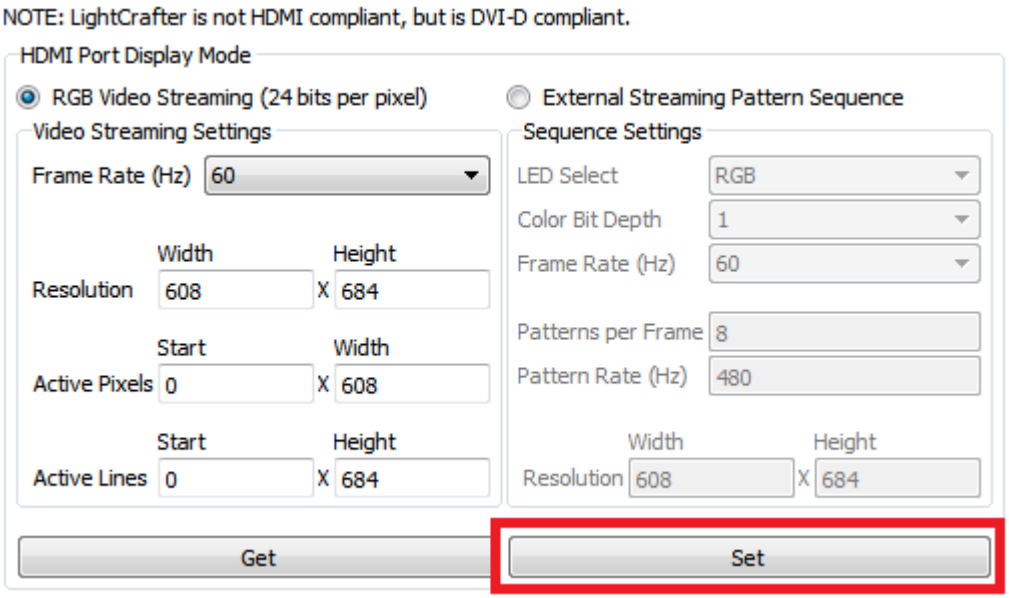

Figure 2-35. DLP LightCrafter GUI RGB Video Streaming Set Button

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8. To retrieve the EVM's current video mode settings, click the Get button.

2.8 Creating Pattern Sequences

The DLP LightCrafter can perform external and internal pattern sequences. External sequences use streaming patterns from the mini-HDMI port. Internal sequences use preloaded patterns and can be stored on the LightCrafter with solutions for reuse. The following sections describe how to set up pattern sequences on DLP LightCrafter.

2.8.1 Internal Stored Pattern Sequences

To create an internal pattern sequence follow these steps:

1. Set the display mode as "Stored Pattern Sequence".
2. Select the "Stored Pattern Sequence", then the "Sequence Settings" tab as shown in Figure 2-36.

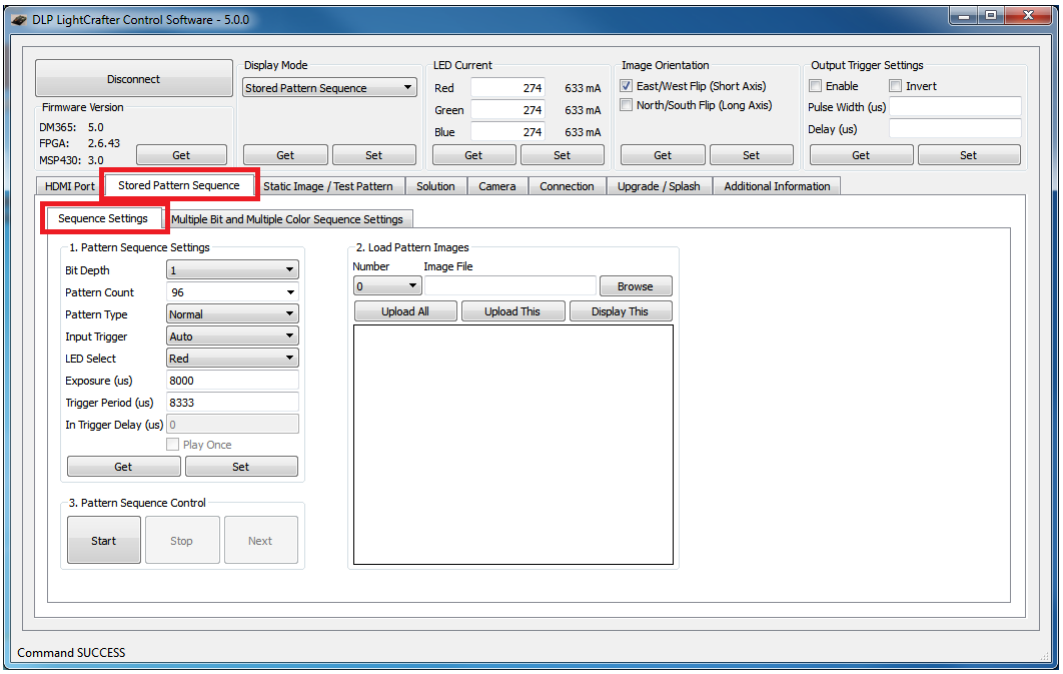

Figure 2-36. DLP LightCrafter GUI Sequence Settings Tab in Stored Pattern Sequence Tab

3. Set Pattern settings by updating the following parameters inside the Pattern Setting box:
   - Bit depth: bit depth of the image. Allowed values are from 1 to 8.
   - Pattern count: amount of patterns to display in sequence. Allowed values 1 to 96 divided by the bit depth. For example, if the bit depth is 8, the maximum amount of patterns is 96 / 8 = 12. If the bit depth is 1, the maximum amount of patterns is 96/1 = 96.
   - Pattern type
     - Normal: display the pattern sequence. Available for all bit depths.
     - Inverted: display the pattern sequence with each pattern followed by its inverted pattern. Available for pattern sequences with bit depth equal to 1.
     - HW pattern: display a pattern sequence created from hardwired (HW) patterns. See *Section 2.8.1.1* for more details.
   - Trigger type: selects how the patterns are triggered.
     - Auto: patterns displayed after end of trigger period.
     - Command: patterns displayed when the Next button is pressed.
     - External (positive): patterns displayed after an external active-high trigger signal.
     - External (negative): patterns display after an external active-low trigger signal.

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- LED select: selects which color LED is active (red, green, or blue). See *Section 2.8.1.2* for details about using the Multiple setting.
- Trigger delay: number of microseconds delay after trigger is received and pattern is displayed. See Figure 2-37.
- Exposure time: number of microseconds the pattern is displayed. Input 0 to display the pattern through the whole trigger period. See Figure 2-37.
- Trigger period: number of microseconds delay between two consecutive patterns. See Figure 2-37.

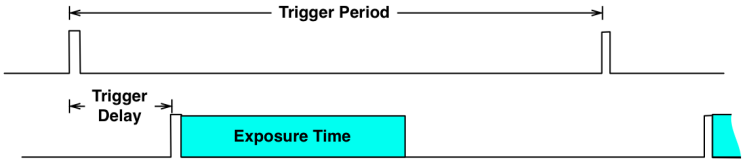

Figure 2-37. Relationship Between Trigger Period, Trigger Delay, and Exposure Time

4. Click the Set button as shown in Figure 2-38.
   - If the exposure or trigger period values are less than the minimum allowed, DLP LightCrafter automatically sets the minimum values.

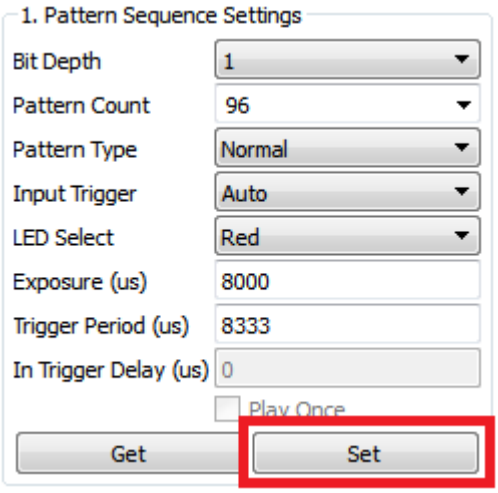

Figure 2-38. DLP LightCrafter GUI Pattern Sequence Settings Set Button

NOTE: Changing the bit-depth, exposure, or pattern count requires that all the images need to be uploaded again. Uploading all images is necessary since the pattern arrangement in the frame memory buffer depends on these settings.

5. Click the Browse button to select the number of bitmap patterns matching the bit depth and number previously set. See Figure 2-39 and Figure 2-40.
   - The pattern number should be set to 0.
   - The patterns must be a BMP file with a resolution of 608 × 684.
   - The pattern file names should have their corresponding pattern numbers within the name (that is 00_PAT, 01_PAT, 02_PAT, and so forth)
     - Each file should have the same number of digits for the pattern number
       - Correct: 00_PAT, 01_PAT, 02_PAT, ... , 10_PAT, and so forth
       - Wrong: 0_PAT, 1_PAT, 2_PAT, ... , 10_PAT, and so forth
   - Click the pattern number drop down list to view the pattern in the GUI. This selected pattern can then be displayed on the EVM by clicking Display This button.

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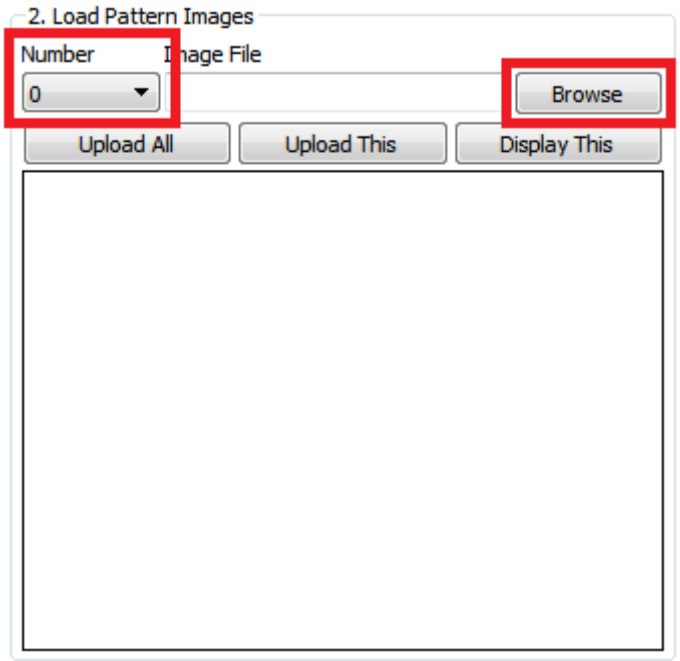

Figure 2-39. DLP LightCrafter GUI Load Pattern Images

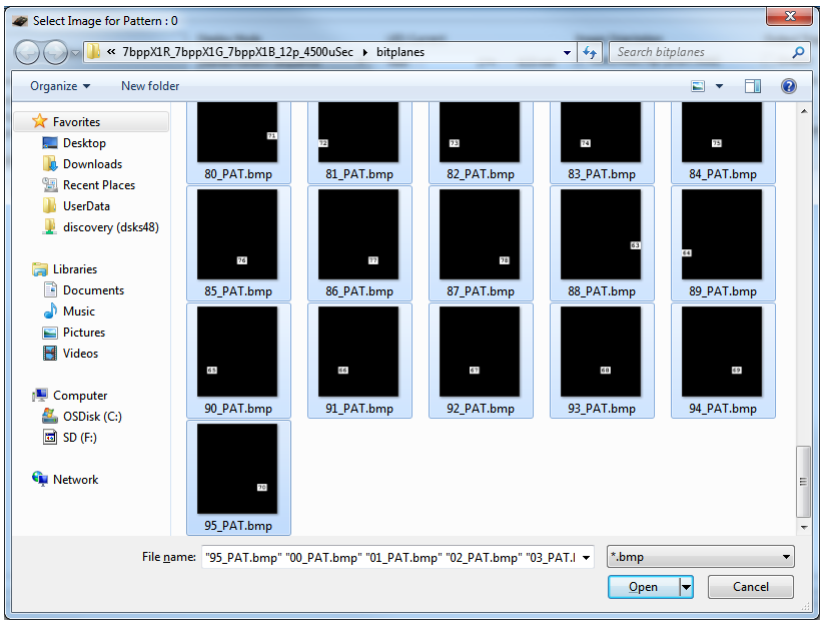

Figure 2-40. DLP LightCrafter GUI Select Images Window

6. Upload the patterns to DLP LightCrafter by clicking the Upload All button as shown in Figure 2-41.

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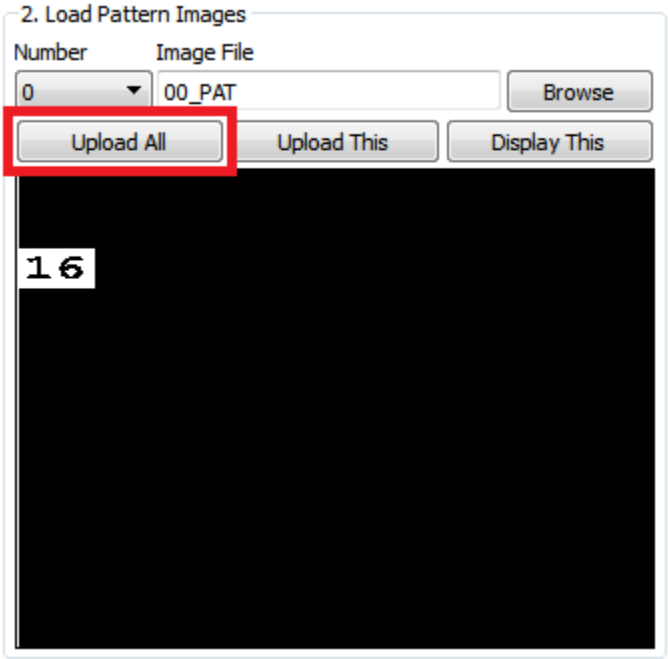

Figure 2-41. DLP LightCrafter GUI Upload All Pattern Images Button

7. Start the pattern sequence by clicking Start as shown in Figure 2-42.

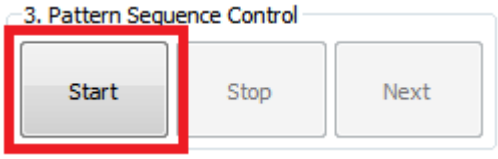

Figure 2-42. DLP LightCrafter GUI Pattern Sequence Control Start Button

2.8.1.1 Hardwired Pattern Sequences

The DLPC300 can generate a set of 15 vertical 1-bit monochrome patterns with its internal pattern generator. These patterns are called hardwired patterns in the DLP LightCrafter GUI. Up to 32 of these vertical patterns can be arranged in any order with or without inversion. The inversion of a pattern converts the black regions to white and the white regions to black. For a description of the available patterns, see Table 2-64 from the *DLPC300 Programmer's Guide*, DLPU004. Pattern numbers 0 through 10 form a set of gray-coded patterns. Pattern numbers 11 through 14 can be used for auto-focus.

The extended pattern sequence mode follows the same steps as those listed in *Section 2.8.1* for regular internal stored pattern sequences except for selecting the images. Rather than clicking the Browse button, select the desired HW Pattern from the dropdown list. See Figure 2-43.

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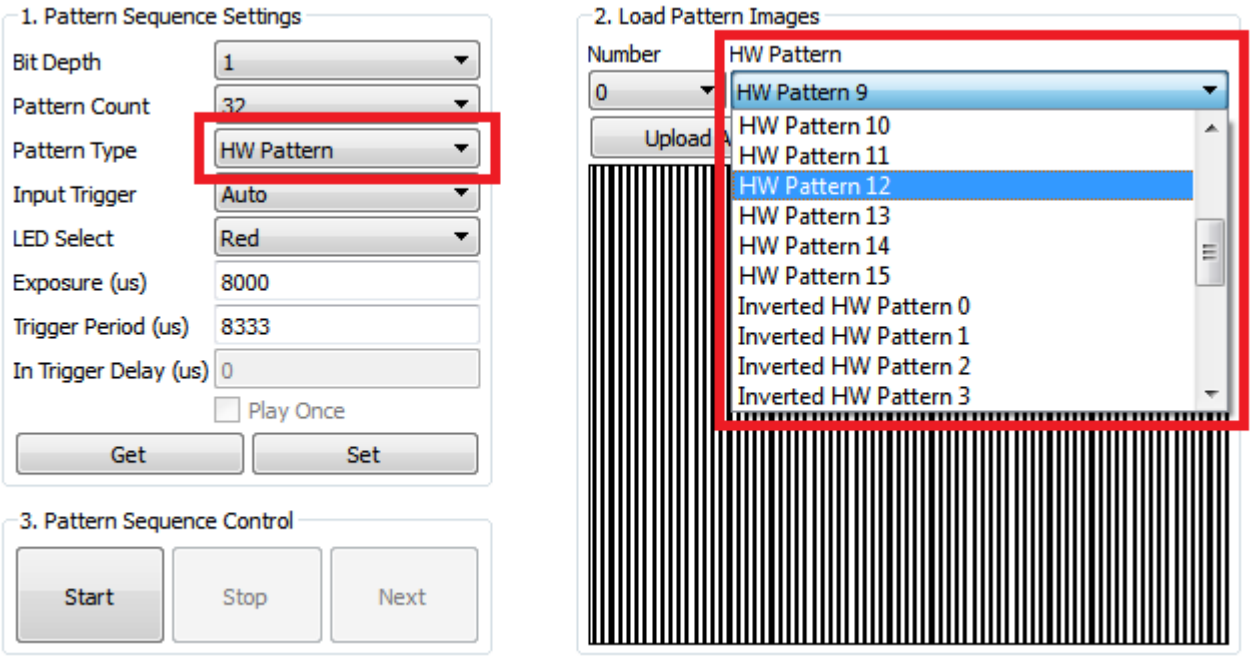

Figure 2-43. DLP LightCrafter GUI Hardwired Pattern Sequence Settings and Pattern Selection

NOTE: While the DLP LightCrafter internally generates hardwired patterns, the Upload All button still needs to be clicked after all hardwired patterns have been selected for each pattern.

2.8.1.2 Multiple Bit-Depth and Multiple Color Pattern Sequences

With the latest FPGA Firmware (version 2.6.43) and DM365 software (version 4 or above), the DLP LightCrafter can run internal pattern sequences that use multiple bit depths and multiple colors (MBMC). To create an MBMC pattern sequence, follow these steps:

1. Submit MBMC pattern sequence requests on TI's E2E forum in the DLP LightCrafter Development Platform subsection (http://e2e.ti.com/) by creating a post titled "MBMC Request" and provide the following information:
   - Pattern exposure time (250 µs < PExT ≤ 20000 µs).
     - This parameter influences the maximum bit-depth possible in the sequence for each pattern. For example, if the exposure time is 1000 µs then it is only possible to have 1-bit or 2-bit depth patterns. On the other hand, an exposure time ≥ 8333 µs supports patterns of all bit-depths from 1 to 8. See Table 4-3 to find the minimum exposure time for each pattern's bit-depth.
   - Patterns Sequence Information as shown in Table 2-3.
     - Patterns must be listed in the order to be displayed.
     - Depending on the order of patterns with different bit-depths it is possible that there will be unused bit-planes that still count towards the maximum 96 bit-planes. The system does not allow split multiple bit-depth patterns across the 24-bit frame buffer boundaries. For example, in the first row of Table 2-3, there are five, 5bpp patterns. This would translate to 5 × 5 = 25 individual bit planes, but each frame buffer can only accommodate 24 individual binary frames. Therefore, in a pattern sequence of five 5-bit patterns, 20 reside in the first frame buffer, while the last 5-bit plans reside in the next frame buffer. The 5bpp × 5 pattern set actually consumes 29 individual bit planes of the frame buffer:
       - 5bpp × 4 patterns + 4 unused patterns = 24 patterns (from the first frame buffer)
       - 5bpp × 1 pattern = 5 patterns (from the second frame buffer)
       - Results in 24 + 5 = 29 individual binary patterns.

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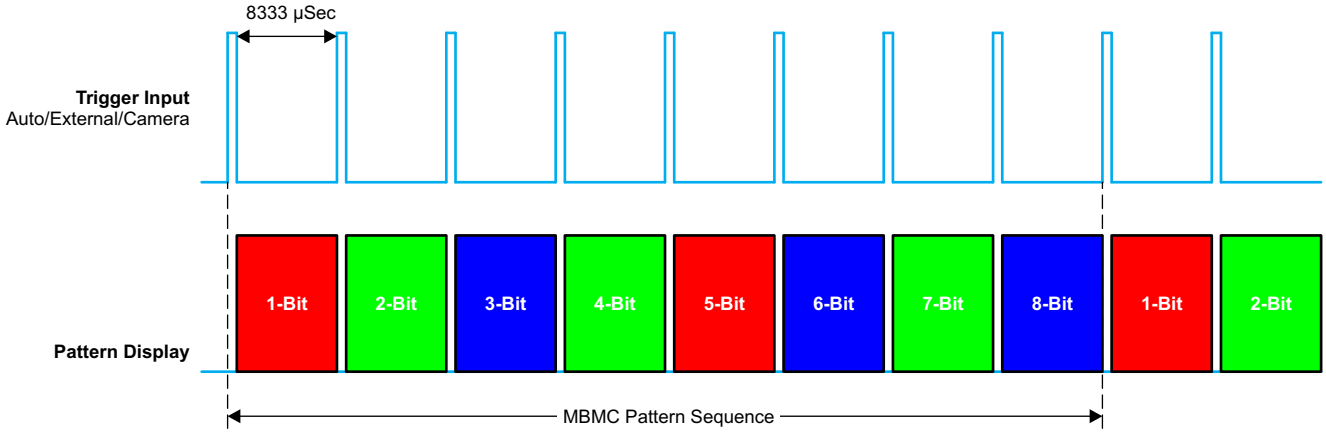
Table 2-3. MBMC Pattern Sequence Information Input

Pattern Bit-Depth	Number of Patterns	Pattern Color (Red/Green/Blue)
5	5	Blue
1	6	Red
..	..	…
..	..	…
7	2	Green
1	3	Blue

- Pattern Sequence Equation in the following form:
  - *<pattern_bit-depth>X<num_of_patterns><color (R)ed or (G)reen or (B)lue>_<pattern_bit-depth>X<num_of_patterns><color (R)ed or (G)reen or (B)lue>_.....<pattern_bit-depth>X<num_of_patterns><color (R)ed or (G)reen or (B)lue>_<exposure_time>µs*
  - For example, 1bppX1G_2bppX1G_3bppX1G_4bppX1G_5bppX1G_6bppX1G_7bppX1G_8bppX1G_8333µs
- The development time frame of the project (optional)
- A description of the application and the need for this capability (optional)



MBMC Pattern Sequence:
1bppX1R_2bppX1G_3bppX1B_4bppX1R_5bppX1G_6bppX1B_7bppX1R_8bppX1G_83333 µSec

Figure 2-44. MBMC Pattern Sequence Output Example

2. Prepare image list file.
   - Create a TXT file.
   - Add one BMP image filename per line.
3. Set Display mode to "Stored Pattern Sequence."
4. Select "Stored Pattern Sequence" tab and "Multiple Bit and Multiple Color Sequence Settings" tabs. See Figure 2-45.

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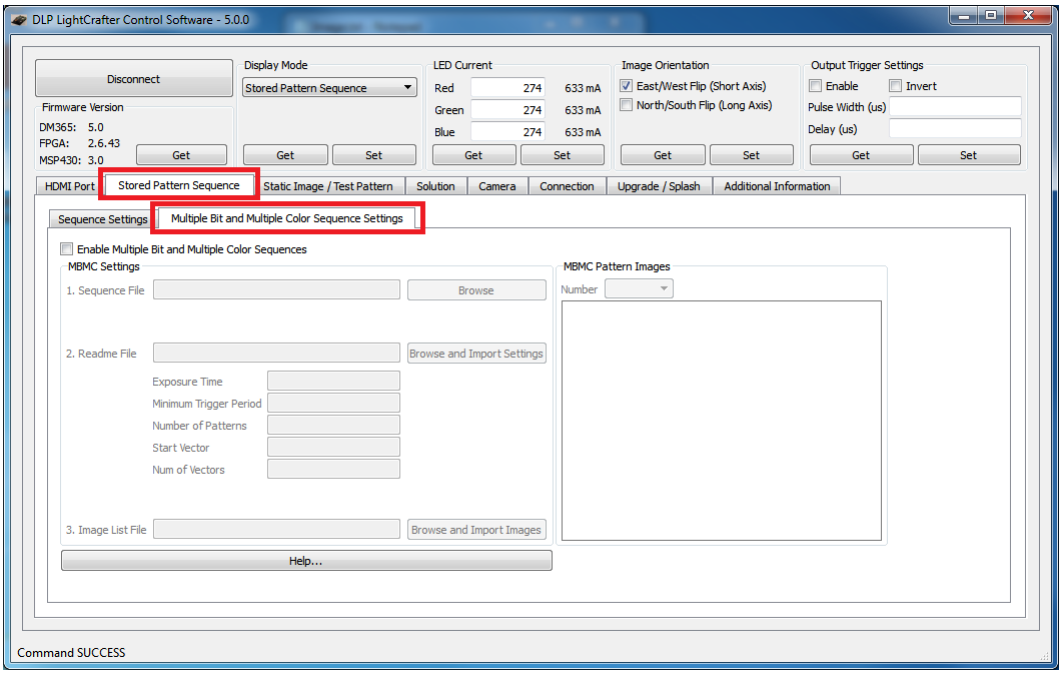

Figure 2-45. DLP LightCrafter GUI Multiple Bit and Multiple Color Sequence Settings Tab in Stored Pattern Sequence Tab

5. Check the "Enable Multiple Bit and Multiple Color Sequences" checkbox. See Figure 2-46.
   - This disables several settings in the "Sequence Settings" tab and requires that a readme file be imported
6. Browse and select the "Sequence File" (.BIN).
7. Browse and Import the settings from the Readme File (.TXT).
   - The GUI automatically imports all the necessary values from the readme file into the GUI.
8. Browse for the "Image List File" and import the images.
   - The GUI automatically parses the images listed in the file into 1bpp patterns and loads them into the GUI. This means that the Browse button in the "Sequence Settings" tab does not need to be used.
   - The GUI displays the MBMC patterns as the DLP LightCrafter will project in the "MBMC Pattern Images" in the "Multiple Bit and Multiple Color Sequence Settings" tab.

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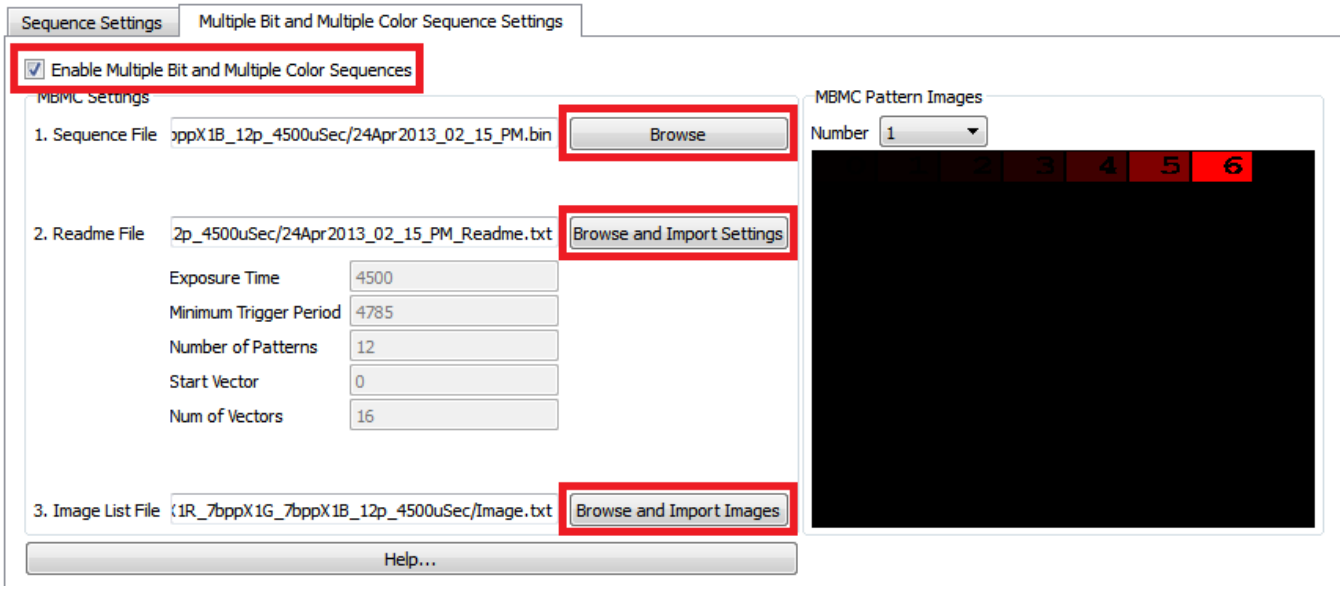

Figure 2-46. DLP LightCrafter GUI Multiple Bit and Multiple Color Sequence Settings Tab in Stored Pattern Sequence Tab

9. Select "Sequence Settings" tab. See Figure 2-47.
10. Click the sequence settings Set button.
11. Click Upload All button.
12. Click Start button.

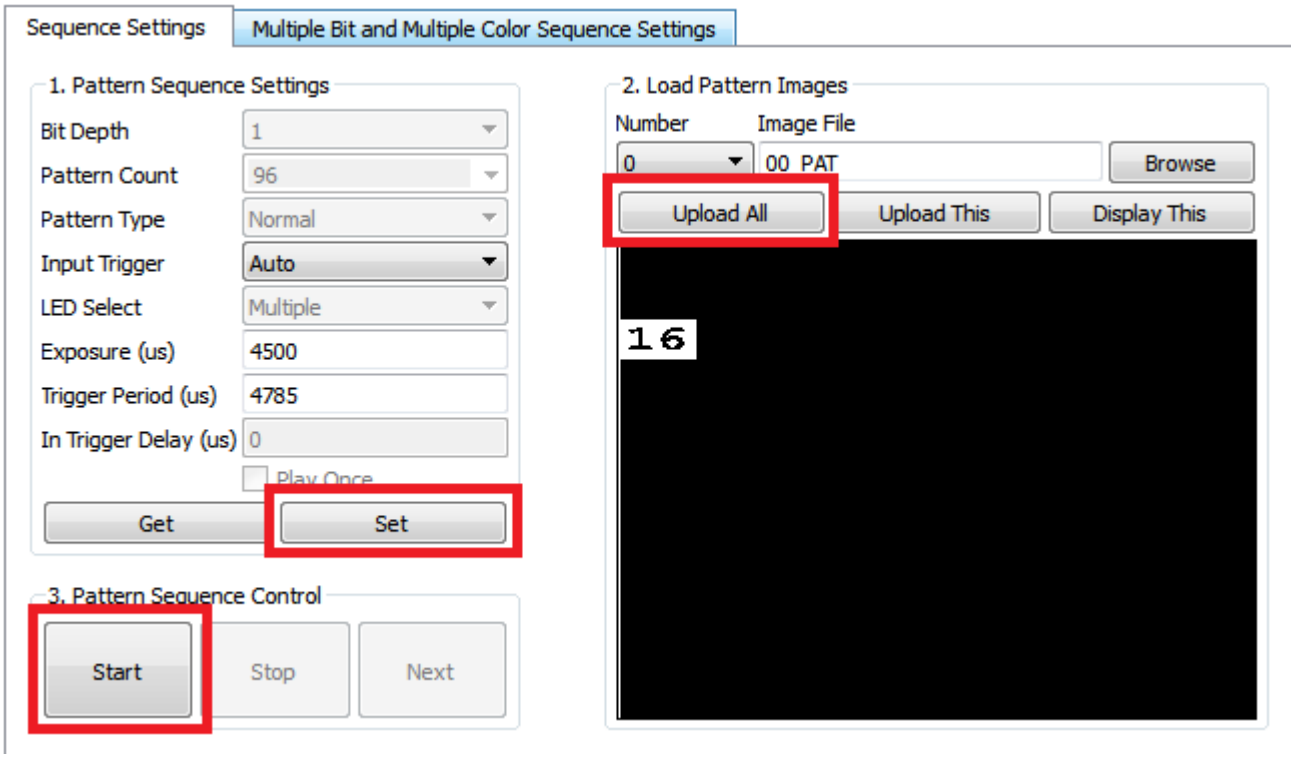

Figure 2-47. DLP LightCrafter GUI Example Sequence Settings for MBMC Sequence

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2.8.2 External Pattern Sequences Streaming from HDMI Port

To create an external pattern sequence follow these steps:

1. Set the display mode as "HDMI Port".
2. Select "External Streaming Pattern Sequence" in the "HDMI Port" tab. See Figure 2-48.
3. Set the LED Select.
4. Set the Color Bit Depth.
5. Set the Frame Rate.
6. Click Set.
   - The GUI calculates the patterns per frame and pattern rate from the bit depth and frame rate.
   - The resolution in "External Streaming Pattern Sequence" mode cannot be changed. The video stream must supply frames with a 608 × 684 pixel resolution.

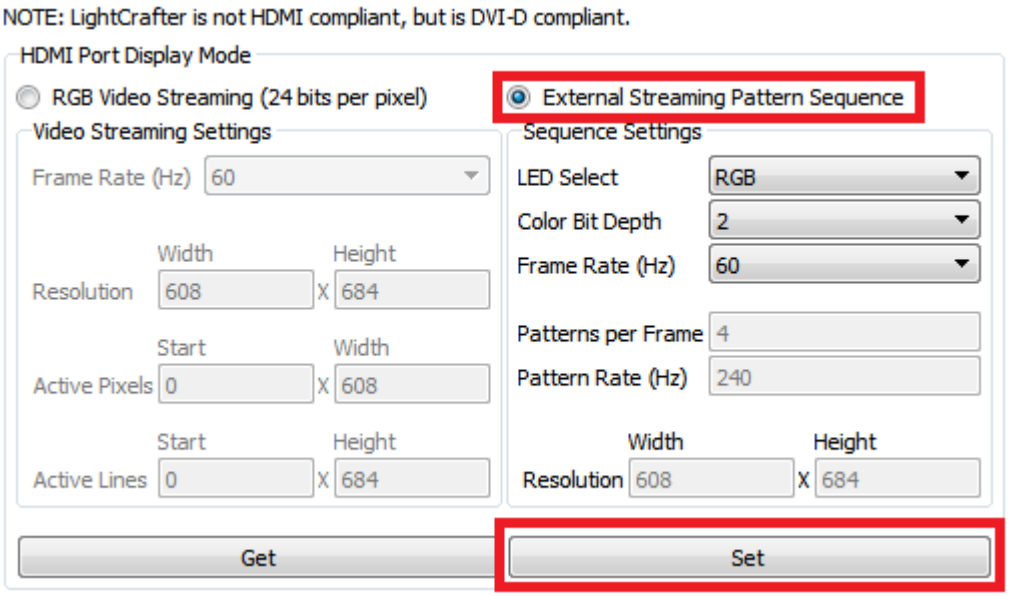

Figure 2-48. DLP LightCrafter GUI External Streaming Pattern Sequence Settings in HDMI Port Tab

2.8.3 Extended Pattern Sequences

In addition to the high-speed internal stored pattern sequences, DLP LightCrafter can run extended pattern sequences that allows more than 96 patterns and exposure times up to 5 s. [1] There are some constraints to the extended pattern sequence mode:

- Sequences with more than 96 patterns are stored in the DDR DRAM 128MB memory connected to the DM365 chip. So the maximum number of patterns allowed in this mode depend on free RAM space after loading DM365 Linux Kernel and Root file system in the DDR memory. With the official unmodified DM365 firmware build, the maximum number of patterns allowed in extended pattern sequence mode is:
  - Approximately 1000 1-bit per pixel patterns
  - Approximately 125 8-bit per pixel patterns
- Longer exposures than 20 ms:
  - Maximum exposure of 5 s for 8-bit per pixel patterns
  - Maximum exposure of 2 s for 1-bit per pixel patterns
- Exposure times longer than 20 ms have to be multiples of 20 ms (for example, 20 ms, 40 ms, 60 ms, and so forth).

[1] Multiple bit and multiple color pattern sequences are not enabled in extended pattern sequence mode.

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- Minimum trigger period of 18 ms
- Minimum exposure of 5 ms
- "Play Once" not supported
- A 330-µs dark frame occurs every 20 ms
- "Multiple Bit and Multiple Color" mode not supported
- FPGA firmware must be version 2.4.39 or newer

The extended pattern sequence mode follows the same steps as those listed in *Section 2.8.1* for regular internal stored pattern sequences except for selecting the pattern count. Type in the pattern count instead of selecting an item from the dropdown list.

NOTE: For the extended pattern sequences to work, the following hardware modifications are mandatory for kits without 2.0 label:

- Install resistor R205 or install a 0-Ω resistor
- Remove resistor R202

2.9 Uploading Static Images or Colors

To upload a 608 × 684 pixel 24-bit RGB Windows bit-mapped image (*.BMP) or display a static color, follow these steps:

1. Set Display Mode to “Static Image / Color.”
2. Select “Static Image / Test Pattern” tab. See Figure 2-49.

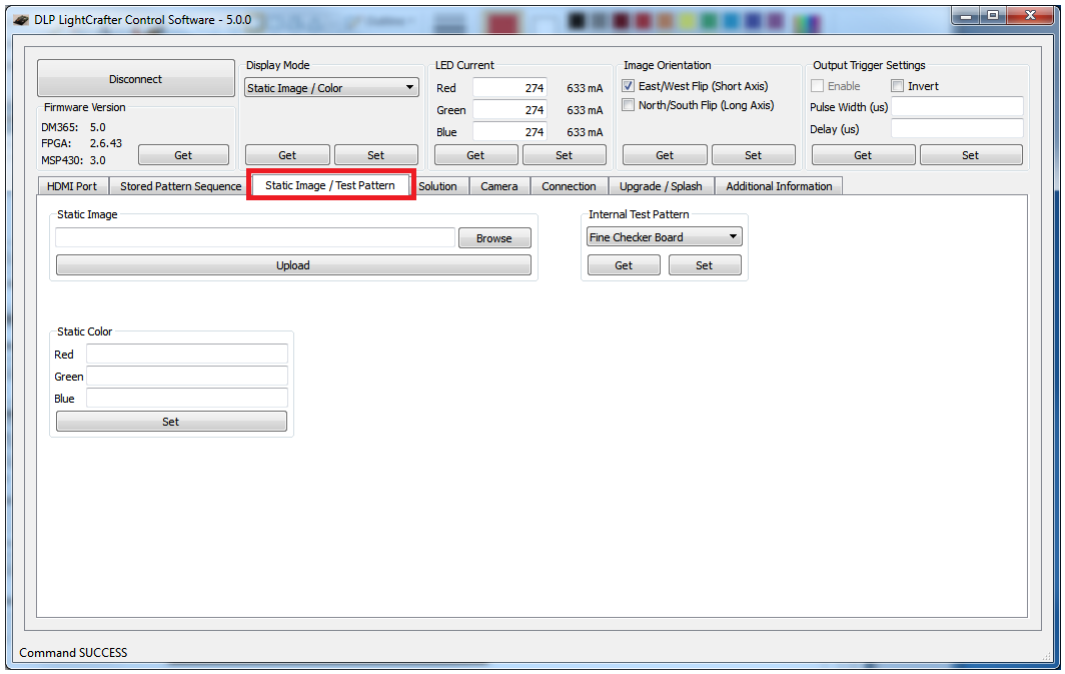

Figure 2-49. DLP LightCrafter GUI Static Image and Test Pattern Tab

3. To display a 608 × 684 pixel 24-bit RGB image, click the Browse button to select the BMP file and then click the Upload button. See Figure 2-50.

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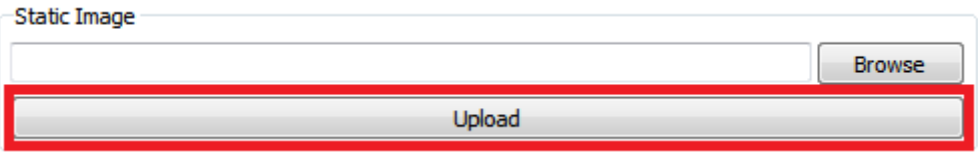

Figure 2-50. DLP LightCrafter GUI Static Image Upload Button

4. To display a solid color, enter an 8-bit value (0 to 255) for each color in the Static Color settings and click Set. See Figure 2-51.
   - For each LED, 0 corresponds to total darkness and 255 to maximum brightness according to the LED's current setting.

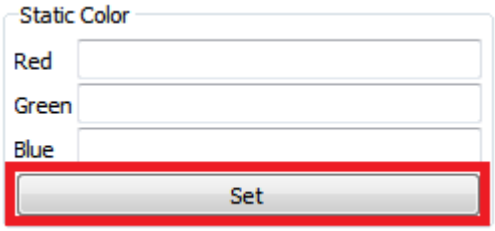

Figure 2-51. DLP LightCrafter GUI Static Color Set Button

2.10 Using Test Patterns

To display DLPC300 internal test patterns, follow these steps:

1. Set Display Mode to “Test Pattern".
2. Select “Static Image / Test Pattern” tab as shown in Figure 2-49.
3. Pull down the menu under “Internal Test Pattern” and select the desired option. The options are:
   - Fine Checker Board
   - Solid Black
   - Solid White
   - Solid Blue
   - Solid Red
   - Vertical Lines
   - Horizontal Lines
   - Vertical Lines (Fine)
   - Horizontal Lines (Fine)
   - Diagonal Lines
   - Vertical Gray Ramp
   - Horizontal Gray Ramp
   - ANSI 4 × 4 Checker Board
4. Click the Set button to display the selected pattern. See Figure 2-52.

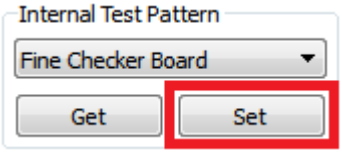

Figure 2-52. DLP LightCrafter GUI Internal Test Pattern Settings

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2.11 Saving and Loading Solutions

Any of DLP LightCrafter's current settings can be stored as a solution. This solution can later be recalled or set to run as the default solution which starts after booting. To create a solution, follow these steps:

1. Set the appropriate settings such as LED Current, Pattern Sequence bit depth, number of patterns, input trigger, trigger period, exposure, time, display mode, and so forth.
2. Click on "Solution" tab as shown in Figure 2-53.
3. Type in the solution name and click “Save.”
4. To manage stored solutions, use the following buttons:
   - Load: load the selected solution
   - Default: sets the selected solution as the default solution when DLP LightCrafter boots; in the list, this solution will be colored blue
   - Delete: erases the currently selected solution
   - Refresh: lists stored solutions

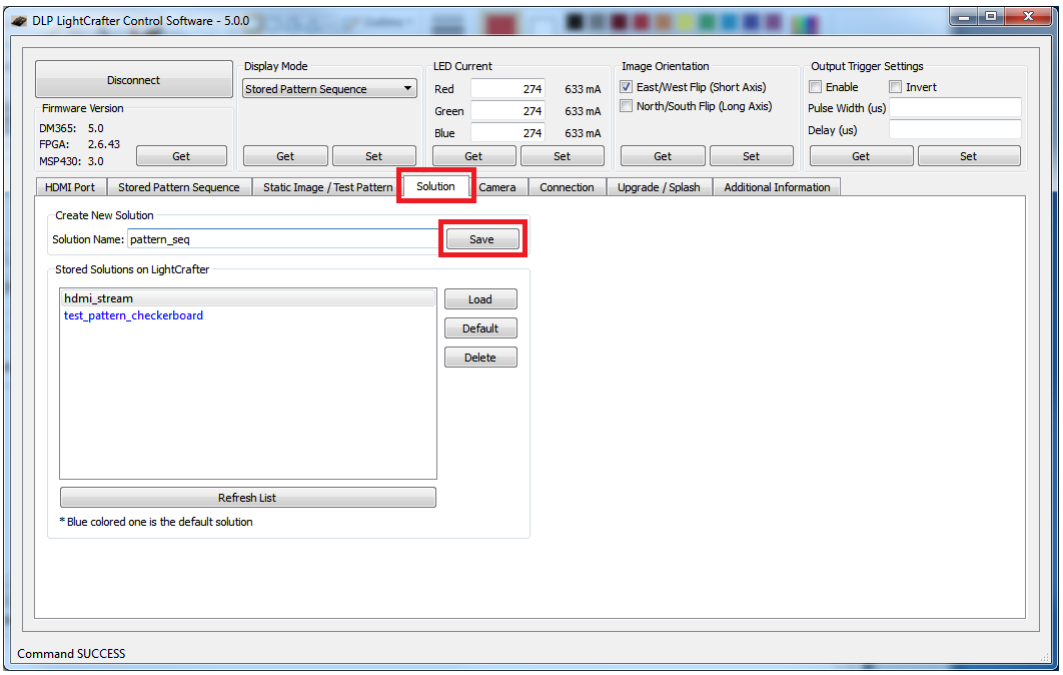

Figure 2-53. DLP LightCrafter GUI Solution Tab

2.12 Capturing Images using the Camera Connector

The DLP LightCrafter's embedded Linux system comes with the MT9P031 camera sensor driver. By connecting this sensor to camera connector (item 14 in Figure 1-7), the EVM can capture images from the sensor and send the image to the computer or to the DMD. For details about the connector, see *Section 5.2*. The camera must be connected to DLP LightCrafter before the EVM boots to ensure the sensor is detected.

To capture an image from the sensor and save the image to the PC, follow these steps:

1. Select the "Camera" tab as shown in Figure 2-54.
2. Click the Capture button.
3. Click the Save button.
4. To capture an image from the sensor and send the image to the DMD, click the Preview button.

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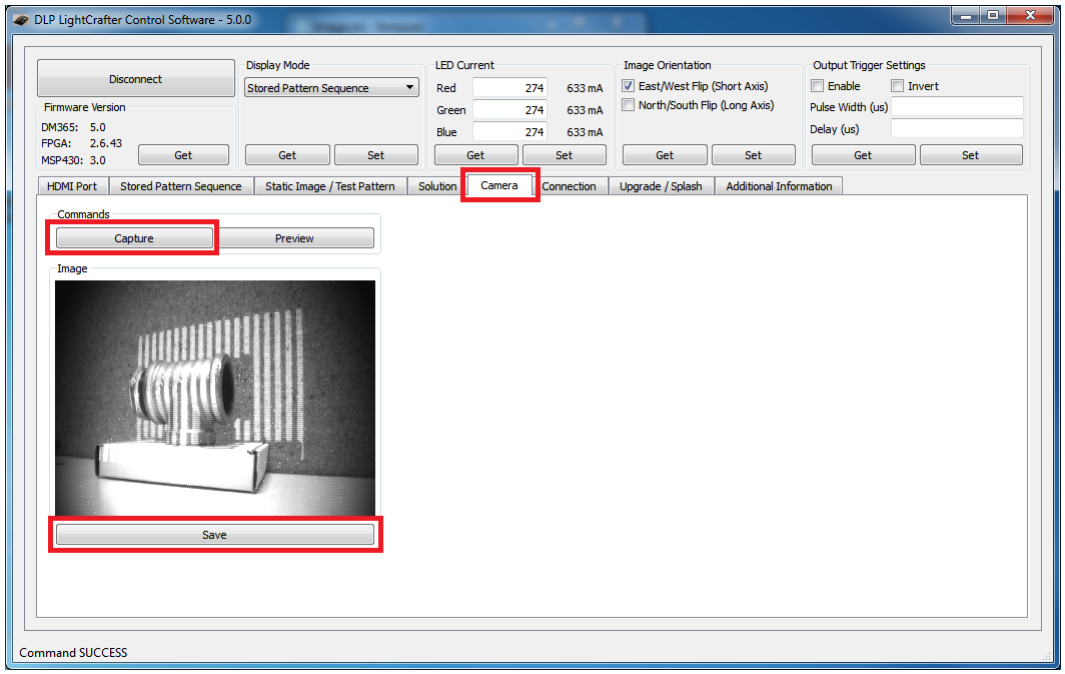

Figure 2-54. DLP LightCrafter GUI Camera Tab

2.13 Upgrading Firmware

Periodic upgrades to the firmware of the FPGA, DLPC300, MSP430, and EDID are accomplished through the DLP LightCrafter GUI. To upgrade the DM365 firmware, a micro-SD card with the new software is needed to load the software into the NAND flash.

2.13.1 Updating the MSP430, FPGA, DLPC300, or EDID Using the GUI

To upgrade the FPGA, DLPC300, MSP430, or EDID, perform the following steps:

1. Select the "Solution / Splash" and "Firmware Upgrades" tabs as shown in Figure 2-55.

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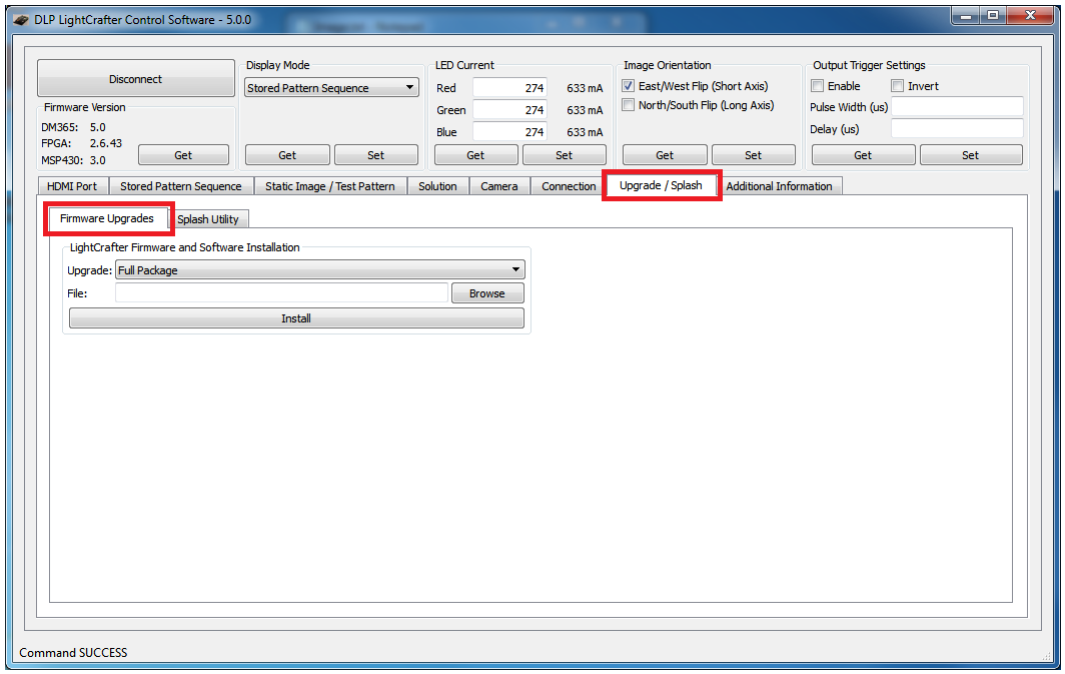

Figure 2-55. DLP LightCrafter GUI Firmware Upgrade Tab

2. Select which firmware to upgrade and then click the Browse button as shown in Figure 2-56.
   - To upgrade MSP430 firmware, select a TI-tagged file (*.txt).
   - To upgrade FPGA, select an "*.rbf" file.
   - To upgrade DLPC300 firmware, select a binary file (*.bin).
   - To upgrade EDID, select a binary file (*.bin).
     - Read *Section 2.7* for setting the video mode parameters.

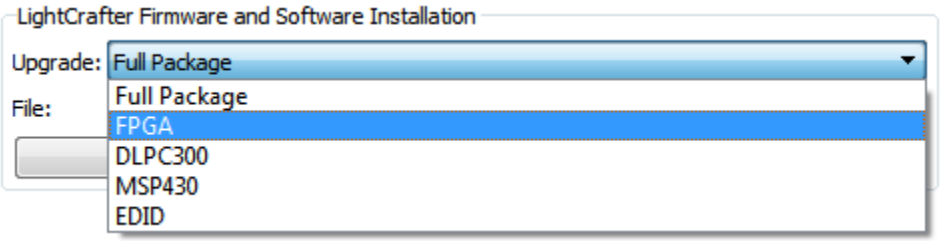

Figure 2-56. DLP LightCrafter GUI Firmware Select Drop-Down Options

3. After the file is selected, click Install as shown in Figure 2-57.

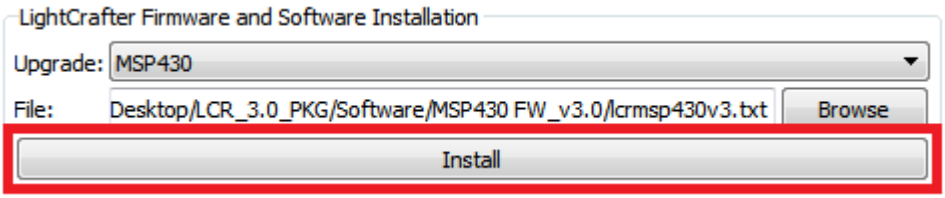

Figure 2-57. DLP LightCrafter GUI Firmware Install Button

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2.13.2 Updating the DM365 Firmware

The DM365 linux system can be loaded from either the NAND flash or SD card. To upgrade the linux system on the NAND, the linux file system must be copied from an SD card into the NAND. Before the file system can be installed into NAND or booted from the SD card, the linux file system must be copied to an SD card. For instructions on how to setup the SD card, see *Section 2.13.2.1* or *Section 2.13.2.2*. After the SD card has been setup, see *Section 2.13.2.3* to install the file system into NAND, or *Section 2.13.2.4* to boot from the SD card.

NOTE: Updating DLP LightCrafter's DM3654 firmware removes all stored solutions from the EVM.

CAUTION

TI does not recommend using SDHC cards for firmware upgrades. For a list of tested SD cards, visit the TI wiki for SD card boot and flashing tool for DM355 and DM365

2.13.2.1 Setting up the SD Card on Windows

To setup the SD card on a Windows systems, follow these steps:

1. Insert micro-SD card into PC
2. Right-click on the SD card from My Computer as shown in Figure 2-58 and select "Format..."

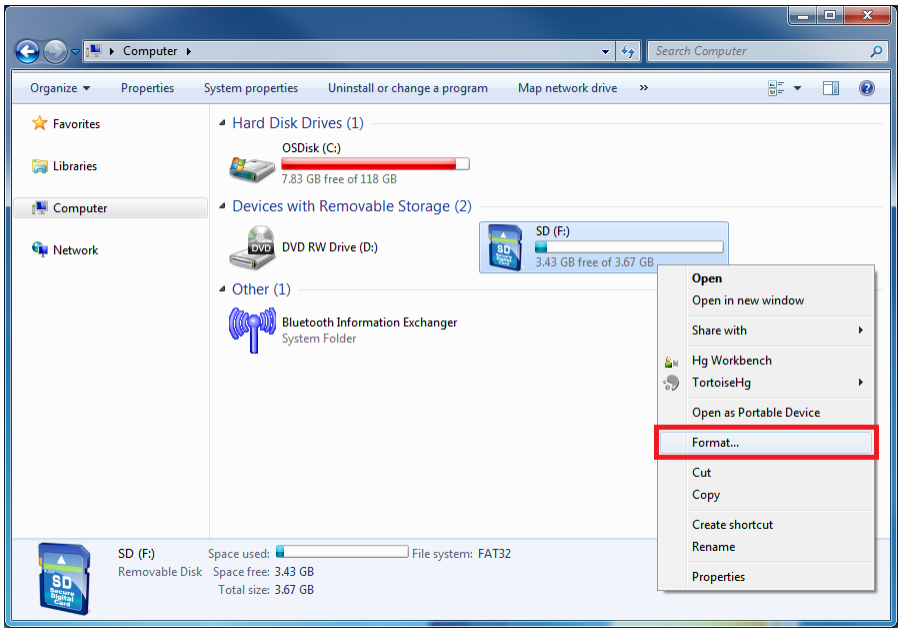

Figure 2-58. Windows 7 SD Card Right-Click Menu

3. Select "FAT32 (Default)" as the file system and use the default values for the other settings. See Figure 2-59.
4. Click the Start button.

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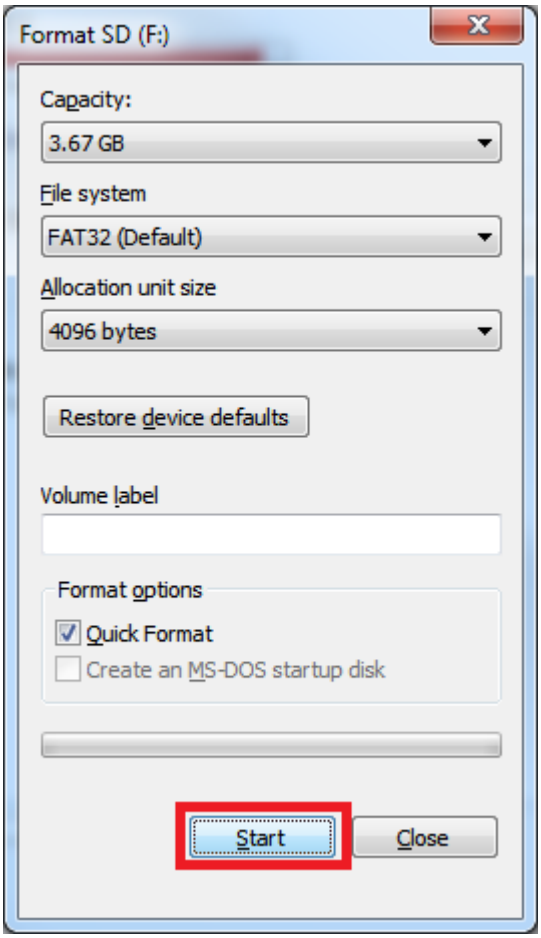

Figure 2-59. Winodws 7 Format SD Card Window

5. Run the "Windows Command Processor" as an administrator. See Figure 2-60.

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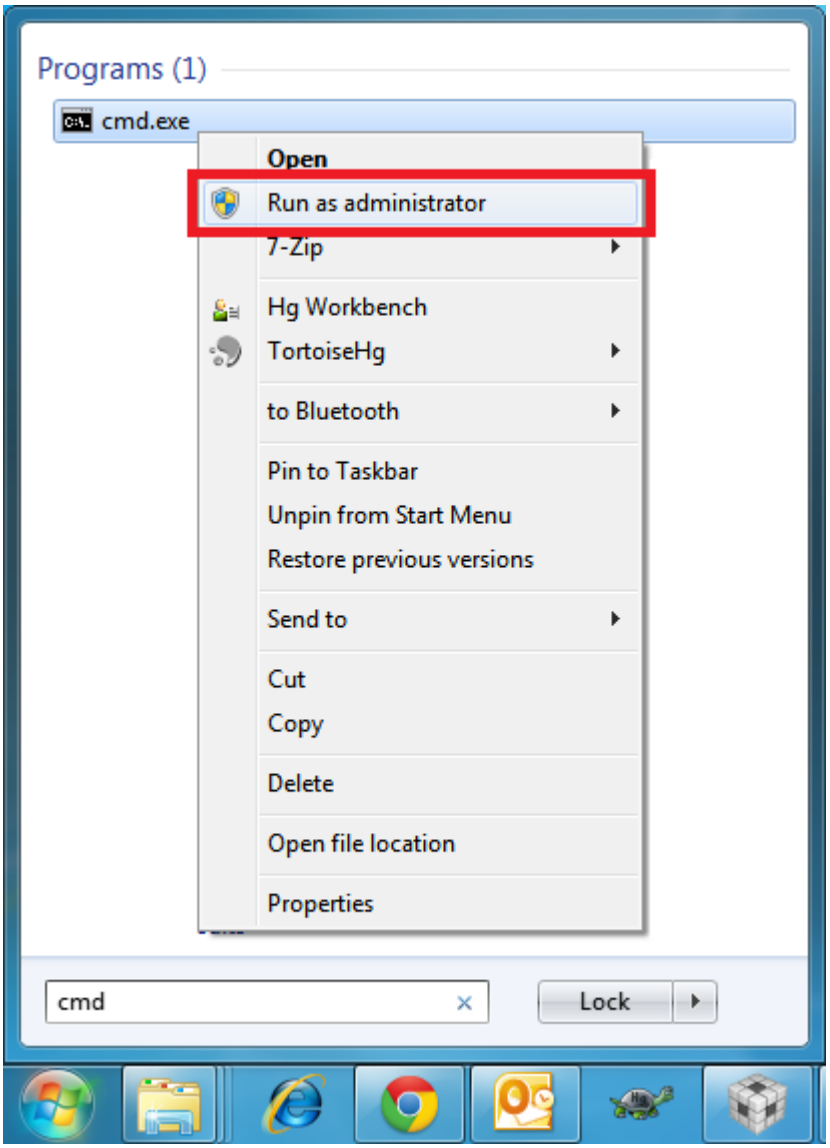

Figure 2-60. Windows 7 Run cmd.exe Right-Click Menu

6. Change to the directory with the DM365 firmware (*.dat) and lcr_boot_sd.exe using the "cd" command. See Figure 2-61.
7. In the "Windows Command Processor" run *lcr_boot_sd.exe {DM365 firmware file} E:* for a SD card mapped to the E: drive.
   - To create a bootable SD card, use the dm3xx_sdv*.dat firmware.
   - To create a SD card to flash the DLP LightCrafter NAND, use the dm3xx_nandv*.dat firmware.

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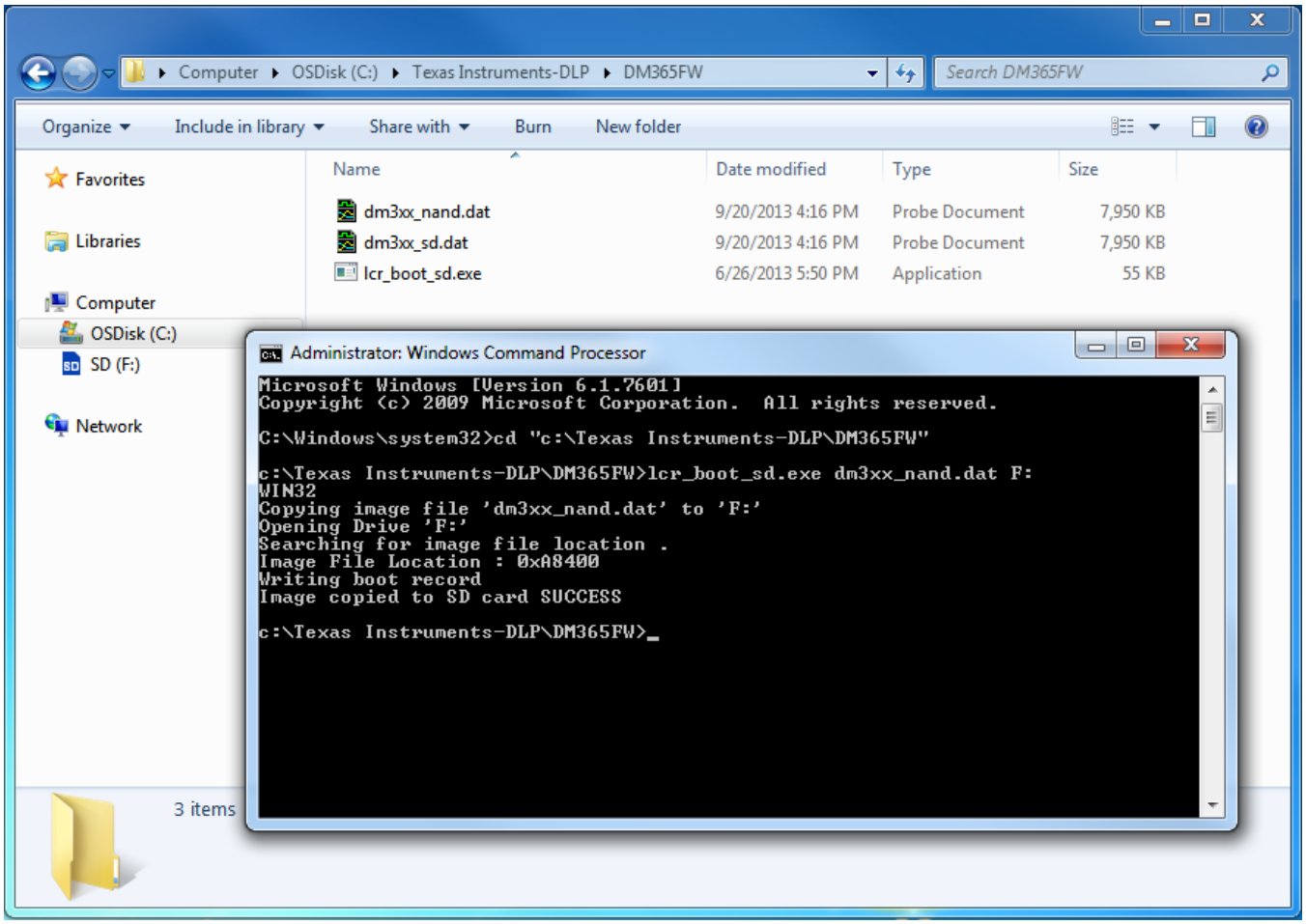

Figure 2-61. Windows 7 Create Bootable SD Card Program

2.13.2.2 Setting up the SD Card on Linux

To setup the SD card on Linux or Mac systems, follow these steps:

1. Insert micro-SD card into PC and allow it to mount.
   - Do not format the SD card. The script formats the card itself.
2. Change to the directory with the DM365 firmware (*.dat) and lcr_boot_sd.sh using the "cd" command.
3. Make the script an executable by running *sudo chmod +x lcr_boot_sd.sh*
4. Run the script *./lcr_boot_sd.sh -f <sd device> <image file>*
   - For example, *./lcr_boot_sd.sh -f /dev/sdb dm3xx_sd.dat*
   - To create a bootable SD card, use the dm3xx_sdv*.dat firmware.
   - To create a SD card to flash the DLP LightCrafter NAND, use the dm3xx_nandv*.dat firmware.
   - If an “umount: device is busy” or “failed to copy the image to SD card” error occurs, try rerunning the script.

2.13.2.3 Installing the DM365 Firmware into the NAND

To install the DM365 firmware into the NAND flash, follow these steps:

1. Insert micro-SD card with firmware into an unpowered DLP LightCrafter.
2. Set the DIP switch on system board to the side closest to the micro-SD card connector.
3. Power up the DLP LightCrafter and the LED next to DM365 lights up red.

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4. Wait until the LED next to DM365 lights up green. This should be a few seconds after the fourth splash screen.
5. Remove power from the DLP LightCrafter.
6. Remove micro-SD card from DLP LightCrafter and set DIP switch to the side closest to DM365.
7. Power the DLP LightCrafter. A test screen of colored bars should appear after the splash screen if firmware has been successfully upgraded.

2.13.2.4 Booting from the SD Card

To install the DM365 firmware into the NAND flash, follow these steps:

1. Insert micro-SD card with firmware into an unpowered DLP LightCrafter.
2. Set the DIP switch on system board to the side closest to the micro-SD card connector.
3. Power the DLP LightCrafter. A test screen of colored bars should appear after the splash screens.

2.14 Changing the Splash Screens

The splash images of the DLP LightCrafter's are RGB 427 × 240 pixel images stored in the DLPC300 firmware. To change the splash screens that appear while DLP LightCrafter boots, follow these steps:

1. Select "Upgrade / Splash" and "Splash Utility" tabs.
2. Click the Browse button to select the DLPC300 firmware file for modifying the splash screens.
3. Select the splash screen index.
   - Selecting the index loads the splash screen into the GUI
4. Click the Change button.
5. Select the desired 427x240 RGB 24-bit image for that splash screen index.
   - After selecting, that image is placed in the DLPC300 firmware file selected from step 3
6. Repeat steps 4 through 6 for the other splash screens.
7. Load the DLPC300 firmware file, with the new splash screens, from step 3 into the EVM by following the instructions from *Section 2.13.1*.

2.15 Loading Images from the SD Card With Slideshow Mode

DLP LightCrafter features a slideshow mode which can display large numbers of patterns from the micro-SD card. To use the slide show mode, follow these steps:

1. Format a new micro-SD card a FAT32 file system.
2. Save the required BMP files to the micro-SD card.
3. Create "config.txt" file and save to the micro-SD card.
   - The user can specify the delay between images one time or multiple times in the text file.
   - For example, this config.txt file creates a slideshow where images 1, 2, and 3 display for 5 s, then images 4 and 5 display for 10 s.
4. Push and hold the button (item 11 from Figure 1-7) to enter slideshow mode
5. Before, powering off the DVM push the button again to exit slideshow mode

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Developing with the DLP LightCrafter

This chapter describes the tools needed to develop the DLP LightCrafter GUI, MSP430 firmware, and TI's DVSDK.

3.1 Compiling the GUI Using QT Creator

To compile the DLP LightCrafter GUI, follow these steps:

1. Download QT5.1 from http://qt-project.org/downloads.
2. Install QT5.1.
3. Open QT Creator.
4. Open the "LightCrafterGUI.pro" from the GUI source folder.
5. Build the project.

3.2 Compiling the MSP430 Firmware Using Code Composer

To compile the MSP430 firmware for DLP LightCrafter, follow these steps:

1. Download Code Composer Studio(CCS) v4.0 from the link, http://processors.wiki.ti.com/index.php/Download_CCS
2. Open the CCS and Import the project by navigating to, Project → Import Existing CCS Eclipse Project
3. Browse for the downloaded MSP430v3 source files and click Finish.
4. Compile this by building the project in Release/Debug mode.
5. The build creates a "MSP430.hex" file.
6. Copy the MSP430.hex file from the Debug/ Release folder and Paste it in MSP430v3 directory.
7. Open the MSDOS command terminal and navigate to this location.
8. Execute the MSP430BIN.EXE to merge the Bootstrap loader with this code as follows, MSP430BIN.EXE -b MSP430_BOOT.hex -m MSP430.hex - o lcrmsp430v25_full.hex Where, lcrmsp430v3.hex is the output file name
   - This command creates two files in the same directory: lcrmsp430v25_full.hex lcrmsp430v25_full.txt
9. Using the GUI, load lcrmsp430v3.txt file in the "Upgrade / Splash" tab.
   - The DLP LightCrafter GUI only accepts .txt file for the upgrade.
10. Remove the power and USB cables from the DLP LightCrafter for a complete shutdown.

3.3 Developing With the TI DVSDK

To compile the TI DVSDK for the DLP LightCrafer's DM365, follow these steps:

1. Install the DVSDK Linux build from http://software-dl.ti.com/dsps/dsps_public_sw/sdo_sb/targetcontent/dvsdk/DVSDK_4_00/4_02_00_06/index_FDS.html
   - ./ti-dvsdk_dm365-evm_4_02_00_06 --forcehost
   - --forcehost allows installations on systems other than Ubuntu 10.04
2. Install the Code Sourcery toolchain from https://sourcery.mentor.com/sgpp/lite/arm/portal/release858
3. Install the latest DLP LightCrafter DM365 DVSDK from DLP LightCrafter's tool page www.ti.com/tool/dlplightcrafter
4. Follow the instructions from the "DVSDK for LightCrafter.doc" document installed with DLP LightCrafter DM365 DVSDK.

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Pattern Sequences

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

4.1 Pattern Sequence Background

The DLPC300 device takes as input 16-, 18-, or 24-bit RGB data at up to 60-Hz frame rate. This frame rate is composed of three colors (red, green, and blue) with each color equally divided in the 60-Hz frame rate. Thus, each color has a 5.55-ms time slot allocated. Because each color has 5-, 6-, or 8-bit depth, each color time slot is further divided into bit-planes. A bit-plane is just one-bit representation of all the pixels in the image. A 24-bit image is decomposed into its bit planes in Figure 4-1.

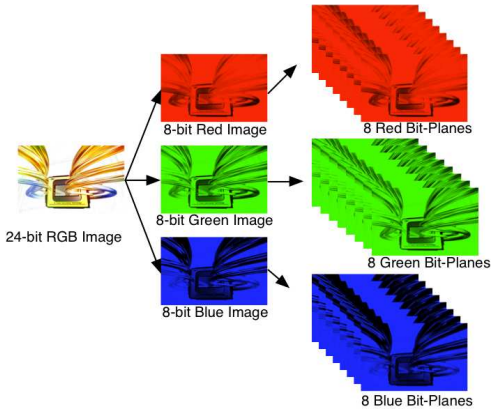

Figure 4-1. Relationship Between Bit Planes and 24-Bit RGB Images

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 shows this partition of bits in a frame.

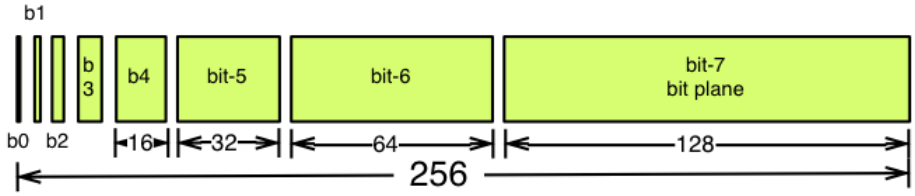

Figure 4-2. Relationship Between Bit Partition and Time

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 the 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 inputted to the DLPC300, the DLPC300 creates 24 bit planes, stores them on the mDDR, and sends them to the DLP3000 DMD, one bit plane at a time. Depending on the bit weight of the bit plane, the DLPC300 device 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 DLPC300 device.

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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 signal a camera to capture these patterns overlaid on an object.

4.2 External Patterns

Using the mechanism described in the previous section, an external device can feed patterns to the DLPC300 for display. Figure 4-3 shows the bit planes and corresponding output triggers for 3-bit, 6-bit, and 12-bit RGB.

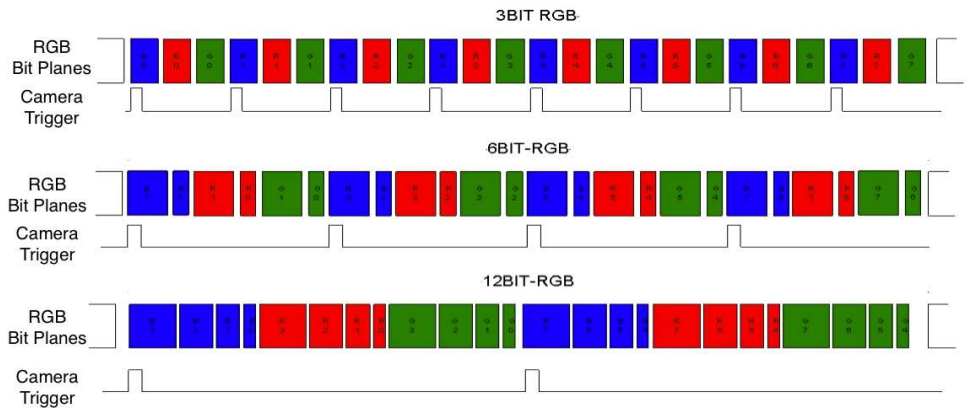

Figure 4-3. Bit Planes and Triggers

While an external device is writing a frame to the DLPC300, the previous frame is displayed. Therefore, there is a lag of one video frame in relation to the output trigger signal.

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

Table 4-1. Allowable External Pattern Combinations

Color Mode		Number of Patterns Per Frame	Frame Rate (Hz)	Pattern Rate
Monochrome	1-bit per pixel	24	15, 30, 45, or 60	24 × Frame Rate
	2-bit per pixel	12		12 × Frame Rate
	3-bit per pixel	8		8 × Frame Rate
	4-bit per pixel	6		6 × Frame Rate
	5-bit per pixel	4		4 × Frame Rate
	6-bit per pixel	4		4 × Frame Rate
	7-bit per pixel	3		3 × Frame Rate
	8-bit per pixel	2		2 × Frame Rate
RGB	1-bit per color pixel (3-bit per pixel)	8		8 × Frame Rate
	2-bit per color pixel (6-bit per pixel)	4		4 × Frame Rate
	4-bit per color pixel (12-bit per pixel)	2		2 × Frame Rate
	8-bit per color pixel (24-bit per pixel)	1		Frame Rate

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4.3 Internal Patterns

In addition to the externally-provided sequences through the 24-bit RGB interface of the DLPC300, the DLP LightCrafter offers the ability to preload patterns into the DLPC300's memory (mDDR) to achieve faster frame rates. After the patterns are preloaded, the FPGA manages the bit planes stored in the mDDR. The mDDR accommodates four 608 × 684 images of 24-bit RGB data or 96 bit-planes (24 bit-planes × 4 images). The bit planes' arrangement and loading procedure is discussed in section 3.2 of *DLP® LightCrafter™ FPGA Overview*, DLPA042

With the FPGA, the pattern frame rate can be calculated with the following equation:

Case 1: If the bit planes can be accommodated in single 24-bit buffer that is number of bit planes ≤ 24

Pattern Rate = 1 / (Pattern Exposure Period) Hz (2)

Case 2: If the bit planes take more than 24-bit buffer that is number of bit planes > 24

Pattern Rate = (1 / Pattern Exposure Period) + (Bit Plane Load Time) + (Buffer Rotate Overhead)

where

- Typical bit plane load time = 230 µs
- Typical buffer rotate overhead = 135 µs (3)

Table 4-2 shows the maximum pattern rate that can be achieved by using a single FPGA's internal buffer in continuous mode.

Table 4-2. Maximum Internal Pattern Rate

Color Mode		Maximum Number of Patterns	Maximum Pattern Rate
Monochrome	1-bit per pixel	96	4000 Hz
	2-bit per pixel	48	1600 Hz
	3-bit per pixel	32	480 Hz
	4-bit per pixel	24	360 Hz
	5-bit per pixel	16	240 Hz
	6-bit per pixel	16	240 Hz
	7-bit per pixel	12	180 Hz
	8-bit per pixel	12	120 Hz

These locally stored patterns have a pre-defined exposure time that is detailed in Table 4-3. Note that the exposure time decrements by 500 µs from the maximum exposure time. Thus, the minimum might not be a step size decrease from the second to last minimum exposure time.

Table 4-3. Internal Pattern Exposure Time

Bit Depth	Maximum Exposure Time (µs)	Minimum Exposure Time (µs)	Step Size Decrease (µs)
8-bit	20000	8333	500
7-bit	20000	4500	500
6-bit	20000	2500	500
5-bit	20000	2000	500
4-bit	20000	1600	500
3-bit	20000	1470	500
2-bit	20000	666	500
1-bit	100000	250	500

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NOTE: The minimum exposure times hold good if the patterns fit into 1-frame buffer 24 bit plane memory else the pattern minimum exposure time is increased by 135 µs.

For example: A pattern sequence consisting of 11 2-bit patterns can be fitted into 1-frame buffer 24-bit plane area and so the minimum exposure time is 666 µs. However, a pattern sequence consisting of 14 2-bit patterns extends into the second buffer, so the user needs to add additional 135 µs as minimum pattern exposure time and it becomes 666 + 135 µs.

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Connectors

This chapter describes the connector pins of the DLP LightCrafter module.

5.1 Trigger Connector

The trigger connector pins are listed in Table 5-1. Two matching four pin mating connector part numbers are:

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

The corresponding crimps part numbers are:

- Molex part number: 50079-8000
- Digi-Key part number: WM1142CT-ND

Table 5-1. Trigger Connector Pins

Description	Pin	Supply Range
Trigger supply	1	3.3 V
Trigger input	2	3.3 V
Trigger output	3	3.3 V
Ground	4	3.3 V

5.2 Camera Connector

The camera connector pins are shown in Table 5-2. The supplies are configurable through resistor population options between 1.8, 2.8, and 3.3 V.

Table 5-2. Camera Connector Pins

Description	Pin	Supply Range
Camera Data[2]	1	2.8 V (CAM_IO)
Camera Data[3]	2	2.8 V (CAM_IO)
Camera Data[4]	3	2.8 V (CAM_IO)
Camera Data[5]	4	2.8 V (CAM_IO)
Camera Data[6]	5	2.8 V (CAM_IO)
Camera Data[7]	6	2.8 V (CAM_IO)
Camera Data[8]	7	2.8 V (CAM_IO)
Camera Data[9]	8	2.8 V (CAM_IO)
Camera PCLK	9	2.8 V (CAM_IO)
Digital Supply	10	1.8 V (CAM_DIGITAL)
I/O Supply	11	2.8 V (CAM_IO)
Ground	12	0 V
Analog Supply	13	2.8 V (CAM_ANALOG)
Camera VSYNC	14	2.8 V (CAM_IO)
Camera HSYNC	15	2.8 V (CAM_IO)
CLKIN 24 MHz	16	2.8 V (CAM_IO)

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Table 5-2. Camera Connector Pins (continued)

Description	Pin	Supply Range
Ground	17	0 V
I^2C SDA	18	2.8 V (CAM_IO)
I^2C SCL	19	2.8 V (CAM_IO)
Camera Reset	20	2.8 V (CAM_IO)
Camera StandBy	21	2.8 V (CAM_IO)
Camera SubAddr	22	2.8 V (CAM_IO)
Camera Data[0]	23	2.8 V (CAM_IO)
Camera Data[1]	24	2.8 V (CAM_IO)
No Connect	25	
Camera Trigger	26	2.8 V (CAM_IO)
Camera DataEn	27	2.8 V (CAM_IO)
No Connect	28	

5.3 UART

The UART connector pins are shown in Table 5-3.

Table 5-3. UART Connector Pins

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

5.4 I^2C

The I^2C connector pins are shown in Table 5-4. Two matching four pin mating connector part numbers are:

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

The corresponding crimps part numbers are:

- Molex part number: 50079-8000
- Digi-Key part number: WM1142CT-ND

Table 5-4. I^2C Connector Pins

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

5.5 Fan

The fan connector pins are shown in Table 5-5. Two matching connector part numbers are:

- Molex part number: 51021-0200
- Digi-Key part number: WM1720-ND

The corresponding crimps part numbers are:

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- Molex part number: 50079-8000
- Digi-Key part number: WM1142CT-ND

Table 5-5. Fan Connector Pins

Description	Pin	Supply Range
Power	1	5 V (SYSPWR)
Switch to ground	2	0 V

5.6 Power

The power connector pins are shown in Table 5-6. Two matching connector part numbers are:

- JST part number: PHR-2(P)
- Digi-Key part number: 455-1165-ND

The corresponding crimps part numbers are:

- JST part number: SPH-002T-P0.5L
- Digi-Key part number: 455-2148-1-ND

Table 5-6. Power Connector Pins

Description	Pin	Supply Range
Input supply	1	5 V (SYSPWR)
Ground	2	0 V

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Revision A History

Changes from Original (January 2011) to A Revision	Page
• Added note about pattern reload when parameters are changed.	36

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

Revision B History

Changes from A Revision (February 2013) to B Revision	Page
• Added *Other Items Needed for Operation* section	15
• Added power connector specifications	15
• Changed and clarified UART mini-plug connection description	15
• Changed PC Software section to reflect changes to installation instructions	18
• Changed note about reload patterns when parameters are changed	36

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

Revision C History

Changes from B Revision (July 2013) to C Revision	Page
• Deleted LED Current section from "What is in this Module"	8
• Clarified that DDR2 memory size is 128MB, not 64MB	12
• Added Software Overview section to DLP LightCrafter Module Overview	13
• Changed embedded Linux Kernel description	13
• Added FPGA Operation section to Software Overview	13
• Added MSP430 Operation section to Software Overview	14
• Added Operating the DLP LightCrafter section	18
• Added Changing the DLP LightCrafter's IP Address section	27
• Added Selecting the Display Mode section	29
• Added Setting the LED Current section	30
• Added Controlling Image Orientation and Rotation section	31
• Added Triggering External Peripherals section	32
• Added Streaming 24-bit RGB Video from the HDMI Port section	33
• Added Creating Pattern Sequences section	35
• Added Uploading Static Images or Colors section	44
• Added Using Test Patterns section	45
• Added Saving and Loading Solutions section	46
• Added Capturing Images using to Camera Connector section	46
• Added Changing the Splash Screens section	53
• Added Loading Images from the SD Card section	53

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

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Revision D History

Changes from C Revision (December 2013) to D Revision	Page
• Added more information regarding the number of patterns supported in extended pattern sequence mode and a note regarding hardware modifications required to operate in this mode	43
• Added more details on pattern frame rate equation and a note that the exposure time increases when the number of patterns is more than 24 bit planes.	57

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