DLP® NIRscan™ Evaluation Module (EVM)

User's Guide

Literature Number: DLPU016B
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Contents

Preface **5**

1 DLP NIRscan Module Overview **8**
- 1.1 Welcome 8
- 1.2 What is in the DLP NIRscan EVM? 8
  - 1.2.1 Optical Engine 10
  - 1.2.2 DLP NIRscan Electronics 12
- 1.3 Other Items Needed for Operation 14
- 1.4 DLP NIRscan Connections 14
- 1.5 DLP NIRscan EVM Jumpers 16

2 Quick Start **19**
- 2.1 Power-Up the DLP NIRscan EVM 19

3 Operating the DLP NIRscan EVM **22**
- 3.1 Quick Scan Mode 23
- 3.2 Custom Scan Mode 25
- 3.3 Slew Scan Mode 30
- 3.4 File Download Icon 34
- 3.5 System Information 34

A Safety **37**

B Power Supply Requirements **39**
- B.1 External Power Supply Requirements 39

C NIRscan EVM Reprogramming Procedure **41**
- C.1 Creating a bootable microSD Card 41
- C.2 Reprogramming the DLP NIRscan EVM Application Software 41
- C.3 Upgrading the DLPC350 Firmware 44

Revision B History **46**

Revision A History **46**

List of Figures

1. DLP NIRscan Evaluation Module 5
1-1. DLP NIRscan EVM Block Diagram 9
1-2. DLP NIRscan EVM Optical Engine 10
1-3. 0.45-Inch DMD Diamond Pixel Geometry 11
1-4. 0.45-Inch DMD Diamond Pixel Array Configuration 11
1-5. Diamond Pixel for Vertical, Horizontal, and Diagonal Lines 12
1-6. DLP NIRscan Electronics 13
1-7. DLP NIRscan EVM Connectors (Backside View) 15
1-8. DLP NIRscan Connectors (Upside-Down Side View) 15
1-9. DLP NIRscan Jumper Locations 16
2-1. DLP NIRscan Homepage 20
3-1. Quick Scan Screen 23
3-2. Example Quick Scan 24
3-3. Example Quick Scan Spectrum Data 25
3-4. Custom Scan Screen 26
3-5. Example Custom Scan 28
3-6. Example Custom Scan Spectral Data 29
3-7. Example Custom Scan Raw Data 30
3-8. Slew Scan Screen 31
3-9. Eample Slew Scan 33
3-10. File Download Screen 34
3-11. Information Screen 35
C-1. MicroSD Card Slot 42
C-2. Boot Switch Location 43
C-3. LED Location 44

List of Tables

1-1. DLP NIRscan EVM Specifications 11
1-2. DLP NIRscan Electronics 14
1-3. Connection Descriptions 15

Read This First

About This Guide

The DLP® NIRscan™ EVM is a third-party implementation of the next generation DLP reference design to enable faster development cycles for spectrometer applications requiring small form factors.

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

This document covers DLP NIRscan Software version 2.0 - version 2.0 is an update to version 1.0 which adds the Slew Scan mode and Custom Scan - Hadamard mode of operation. For instructions on how to update your NIRscan software from version 1.0 to version 2.0, please see Appendix C of this document.

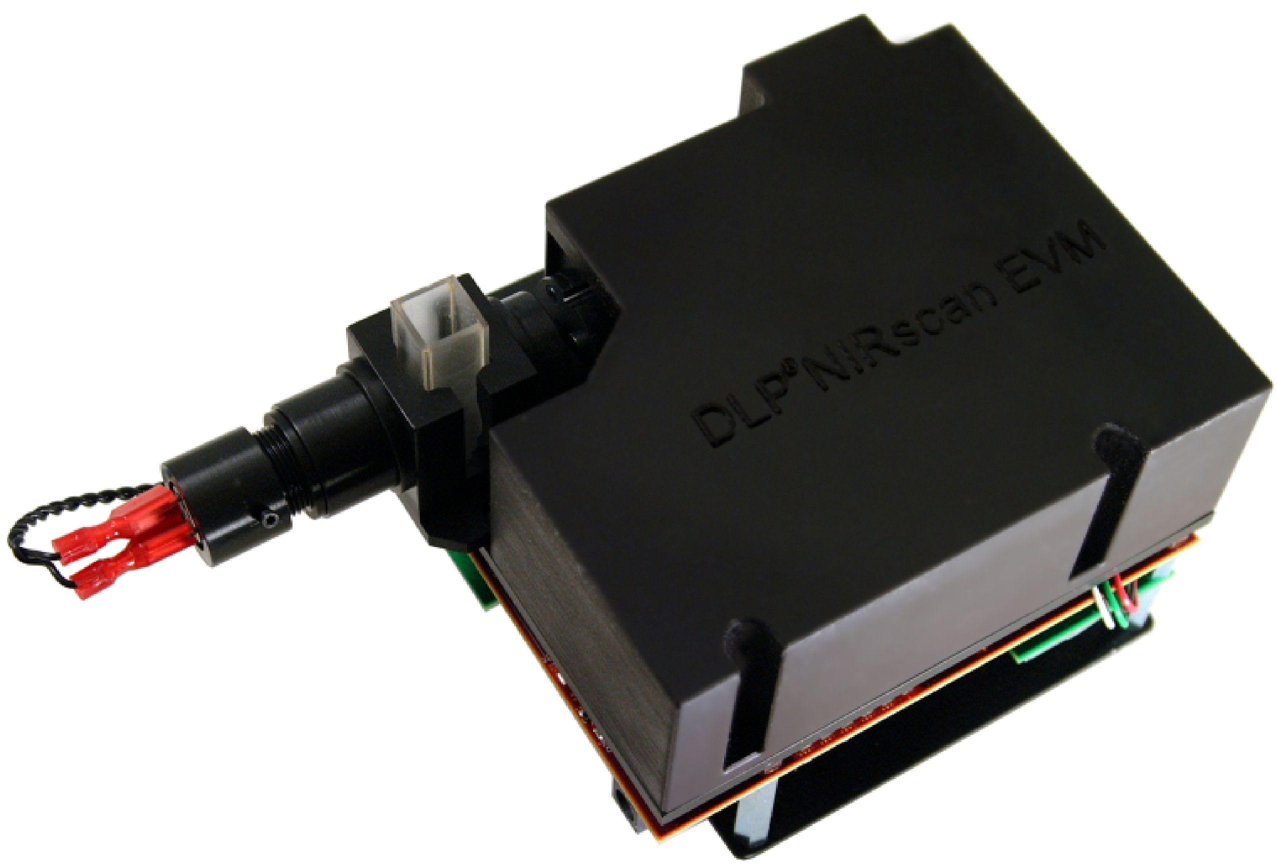

Figure 1. DLP NIRscan Evaluation Module

Users are recommended to use the most recent versions of Firefox, Safari, Google Chrome, or Internet Explorer. There are some compatibility issues noted with IE8 and IE9 so these versions are not recommended.

Related Documentation from TI

DLPC350 data sheet: *DLPC350 DLP Digital Controller for Portable Advanced Light Control*, DLPS029

DLP4500NIR data sheet: *DLP 0.45 WXGA NIR DMD*, DLPS032

Programmer's guide: *DLPC350 Programmer's Guide*, DLPU010

Design guide: *DLP Spectrometer Design Considerations*, DLPA049

If You Need Assistance

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

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DLP NIRscan Module Overview

1.1 Welcome

The DLP® NIRscan™ EVM is a complete evaluation module (EVM) to design a high performance, affordable near-infrared spectrometer. This flexible tool contains everything a designer needs to start developing a DLP-based spectrometer right out of the box. The EVM features the DLP 0.45 WXGA NIR chipset - the first ever DLP chipset optimized for use with near-infrared (NIR) light. With DLP technology, spectrometers for use in the food, pharmaceutical, oil/gas and other emerging industries will be able to deliver lab performance levels in the factory and the field. This technology brings together a set of components providing an efficient and compelling spectroscopy system solution for:

- Process analyzers
- Laboratory equipment
- Dedicated analyzers

The new DLP4500NIR DMD is optimized for operation at wavelengths between 700 and 2500 nm. The DLP NIRscan EVM is one possible implementation of this new DLP technology, operating from 1350 to 2450 nm.

1.2 What is in the DLP NIRscan EVM?

The DLP NIRscan EVM is a complete NIR spectrometer EVM using DLP technology. The EVM package includes:

- Near infrared optomechanical spectrometer engine:
  - Transmissive sample holder with broadband visible-to-infrared tungsten-halogen lamp
  - 25-µm input slit
  - Collimating lenses
  - 1300 to 2500 nm bandpass filter
  - Reflective diffraction grating
  - Focusing lens
  - DLP4500NIR DMD (.45-inch WXGA, 912 × 1140 diamond pixels, NIR optimized)
  - Collection optics
  - 2-mm single-pixel, cooled InGaAs detector
- Electronics subsystem with the electronics consisting of five boards:
  - Spectro board
    - DLPC350 controller ASIC
    - Sitara™ processor (AM3358) for system control and analysis
    - Power management circuits
    - Connectivity through Ethernet and USB
    - Non-volatile eMMC flash memory
    - Micro SD card slot for external programming
    - Open source Linux web-server application software
  - Detector board
    - 2-mm, single-pixel cooled InGaAs detector with TEC and thermistor

    - Low-noise differential amplifier circuit
    - ADS1255 30 kSPS analog-to-digital converter (ADC) with SPI interface
  – Lamp driver board
    - Low noise, constant current supply for the broadband lamp
  – TEC driver board
    - Thermistor feedback signal amplifier for temperature measurement
    - Closed loop TEC current control with high current driver
  – DMD interconnect board
  – Associated cable harnesses
- Three disposable cuvettes, each 12.5 × 12.5 mm with 10-mm path length, for use during the spectrometer evaluation.

Figure 1-1 shows the major hardware components.

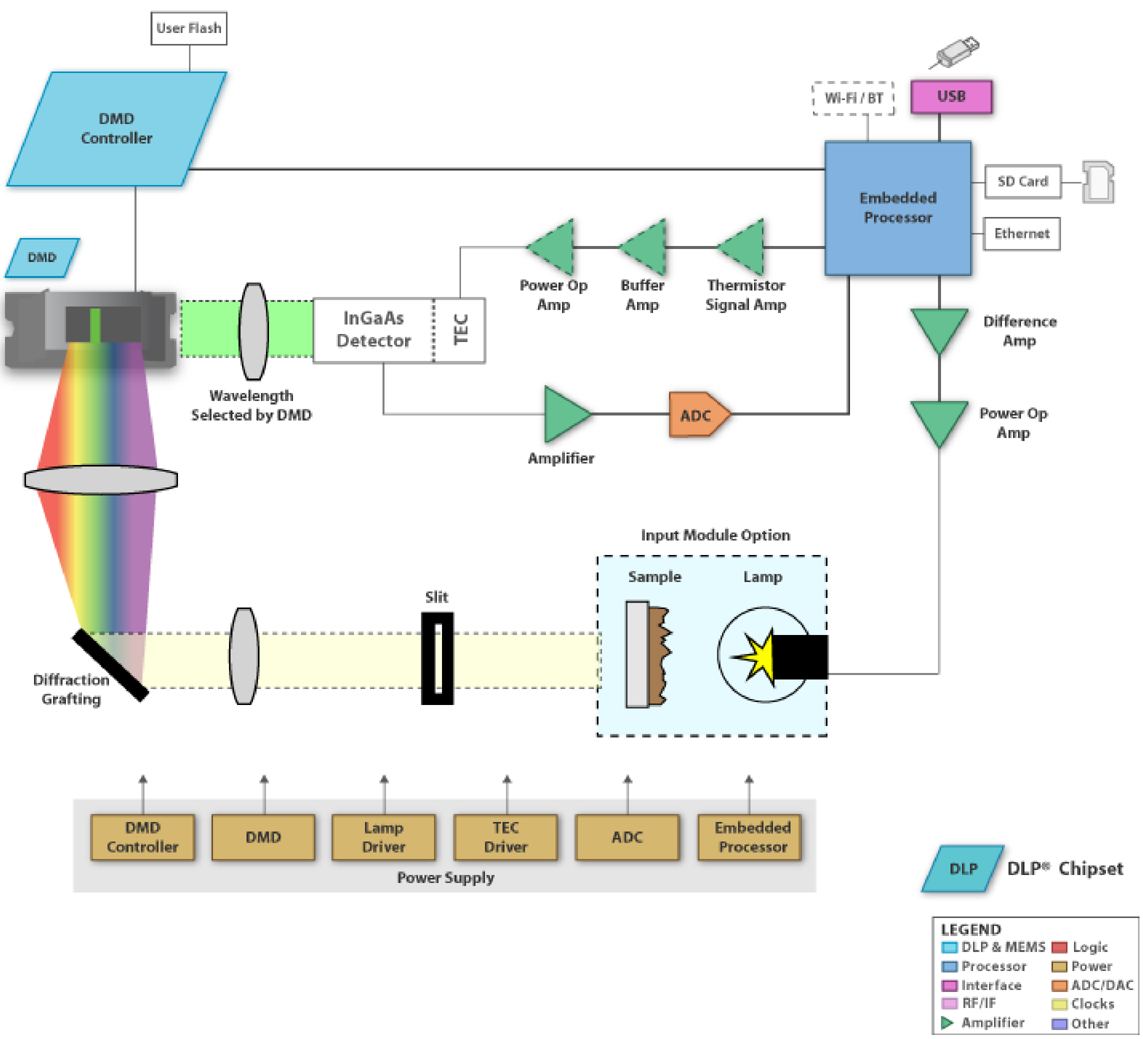


Figure 1-1. DLP NIRscan EVM Block Diagram

1.2.1 Optical Engine

The DLP NIRscan EVM spectrometer optical engine is mounted on top of a thermal plate which acts as a stable platform for mounting the optics. The configuration is a post-dispersive architecture where the broadband light from the tungsten lamp is directed through a transmissive sample. In this specific implementation, the lamp or sample holder module allows insertion of standard cuvettes. These cuvettes are designed to hold liquid samples. There is also a slit in the sample holder, which allows insertion of various thickness NIR transmissive samples such as plastic sheets, coated glass, and so forth. Each sample will pass (and absorb) a specific amount of NIR light through the sample. The amount passed (and absorbed) is dependent on the molecular makeup of the material, and is specific to that material, similar to a fingerprint. The light which passes through the sample enters the engine through the input slit. Slit size is relative to the desired wavelength resolution of the spectrometer. This spectrometer uses a 25-µm wide slit, which is approximately 4.2-mm tall. After light passes through the slit, the light then passes through a collimating lens, through a 1350- to 2450-nm bandpass filter where the light then strikes a reflective grating. This grating, in combination with the focusing lens, disperses the NIR wavelengths across the DLP4500NIR DMD in a horizontal fashion, with 1350 nm projected to one side of the DMD, 2450 nm to the other end, and all wavelengths dispersed between. When specific DMD columns are selected as 'on', or tilted to the +12° position, the energy reflected by the selected columns diverts through the collection optics to the single pixel detector. All other DMD columns which are not selected as 'on' are by default 'off' (tilted to the –12° position). 'Off' DMD pixels divert the unselected wavelengths away from the detector optical path so as not to interfere with the selected wavelength measurement.

The DLP NIRscan EVM size is mostly driven by the size of the optical engine and measures approximately 197-mm long, 112-mm wide, and 96-mm tall.

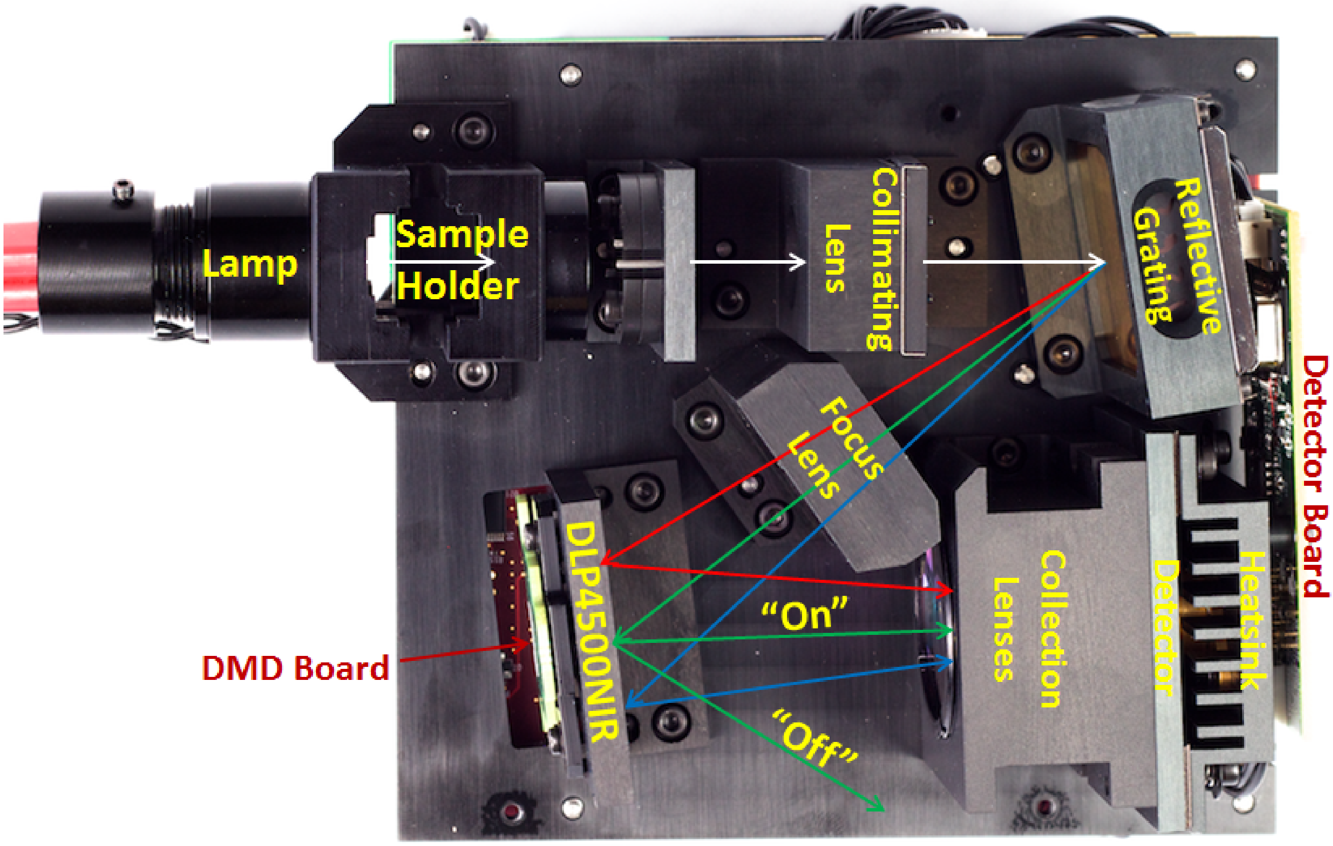


Figure 1-2. DLP NIRscan EVM Optical Engine

CAUTION

Do not disassemble the optical engine. The optical engine contains lenses, gratings, and detectors that have been calibrated at the factory. Loosening or tightening screws and optical components may move pieces out of alignment and cause decreased system performance. Removal of the cover may allow dust intrusion, which can also decrease system performance.

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

Table 1-1. DLP NIRscan EVM Specifications

PARAMETER	MIN	TYP	MAX	UNIT
Supported wavelengths	1350		2450	nm
Spectrometer typical power		12		W
Tungsten lamp typical power		4		W

The optical engine includes the DLP4500NIR 0.45-inch DMD with 1039680 mirrors, arranged in 912 columns × 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. Conceptually, the spectroscopy application running on the DLP NIRscan GUI uses vertical columns to select wavelengths. These vertical lines are programmable in width as selected in the DLP NIRscan GUI software. Wider columns tend to provide more light to the detector, but less digital resolution. Narrow columns provide higher digital resolution, but less light to the detector.

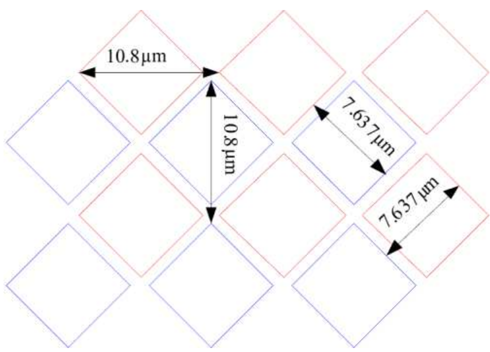


Figure 1-3. 0.45-Inch DMD Diamond Pixel Geometry

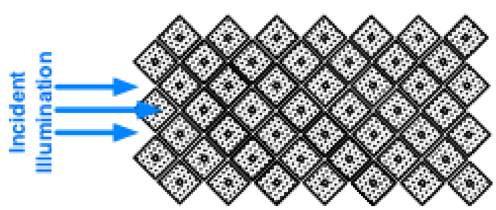


Figure 1-4. 0.45-Inch DMD Diamond Pixel Array Configuration

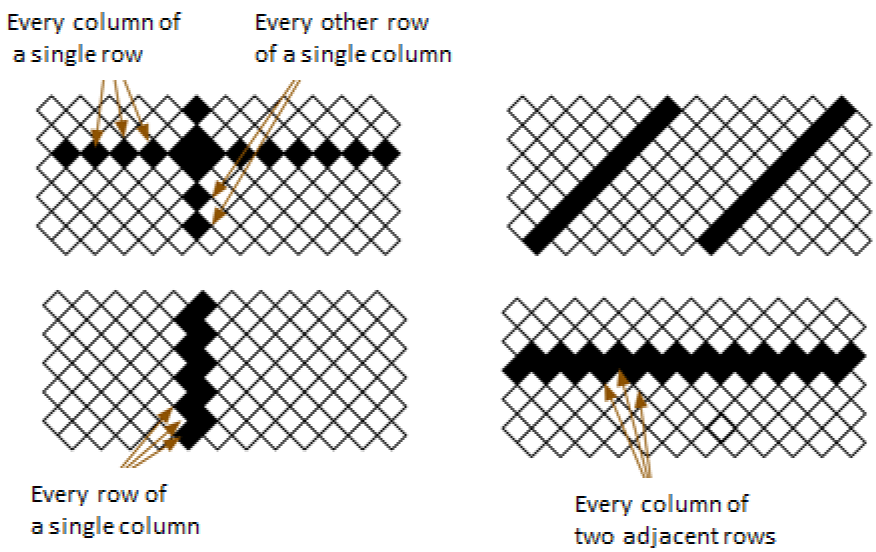


Figure 1-5. Diamond Pixel for Vertical, Horizontal, and Diagonal Lines

1.2.2 DLP NIRscan Electronics

The DLP NIRscan EVM contains five boards which support all the electrical and software capabilities of the spectrometer. The five boards are:

- **Spectro board**: The spectro board is the largest board in the DLP NIRscan EVM. The board provides the following:
  - Sitara processor: The Sitara processor (AM3358) runs a webserver which provides an HTML-based method of controlling the spectrometer and displaying the results of sample scans. The Sitara formulates and streams unique wavelength specific patterns to the DLPC350 for display on the DMD while synchronizing the sampling of the spectrometer's ADC. The Sitara runs a Linux-based spectrometer application on an open source Linux kernel. The user controls the web pages through an RNDIS connection over USB, or by IP address over Ethernet connected to the local area network.
  - DLPC350 ASIC: The controller of the DLP4500NIR-based DLP system, the DLPC350 device receives the pattern data from the Sitara over a 24-bit RGB bus. The DLPC350 decodes the pattern information and converts the information into the correct format for the DMD. The device controls all the DMD signals and synchronization, thereby directing each individual mirror to its desired state.
  - External interfaces: The spectro boards provide multiple interfaces to the outside world. Standard interfaces for communicating with the DLP NIRscan EVM are Ethernet-over-USB and a standard RJ45 ethernet connection. To leverage the DLP NIRscan EVM platform for new product development using the Sitara processor, the spectro board also contains a Sitara debug port, which can be used with console software to control and debug the EVM software.
  - Internal interfaces: The spectro board is at the center of the spectrometer electronics and software. All boards plug into the spectro board though either a hard board connector or wiring harness.
- **DMD board**: The DLP4500NIR DMD is located in the optical engine portion of the system. The DMD board plugs into the spectro board and connects the DLPC350 to the DMD.
- **Detector board**: The detector board is located within the optical engine and connects the InGaAs detector to the TEC driver board. The detector board also houses the differential amplifier circuits which source the detector signal to the TI ADS1255 ADC. The ADS1255 ADC is used to over-sample the resultant signals being routed from the detector for each wavelength-specific pattern being displayed on the DMD.
- **TEC driver board**: The TEC driver board uses the feedback from a thermistor located in the detector to provide electrical current to the detector TEC in a closed-loop control circuit, thereby cooling the

detector to approximately –40°F and reducing detector noise.

- **Lamp driver board**: The lamp driver board provides an extremely-low noise, high-power source for the tungsten-halogen lamp, which illuminates the sample. A low-noise source is important for a spectrometer which has a high signal-to-noise ratio (SNR).

Figure 1-6 shows the spectro, TEC driver, and lamp driver boards. The detector board is located within the optical engine. The DMD board plugs into the backside of the spectro board and connects it to the DMD located inside the optical engine.

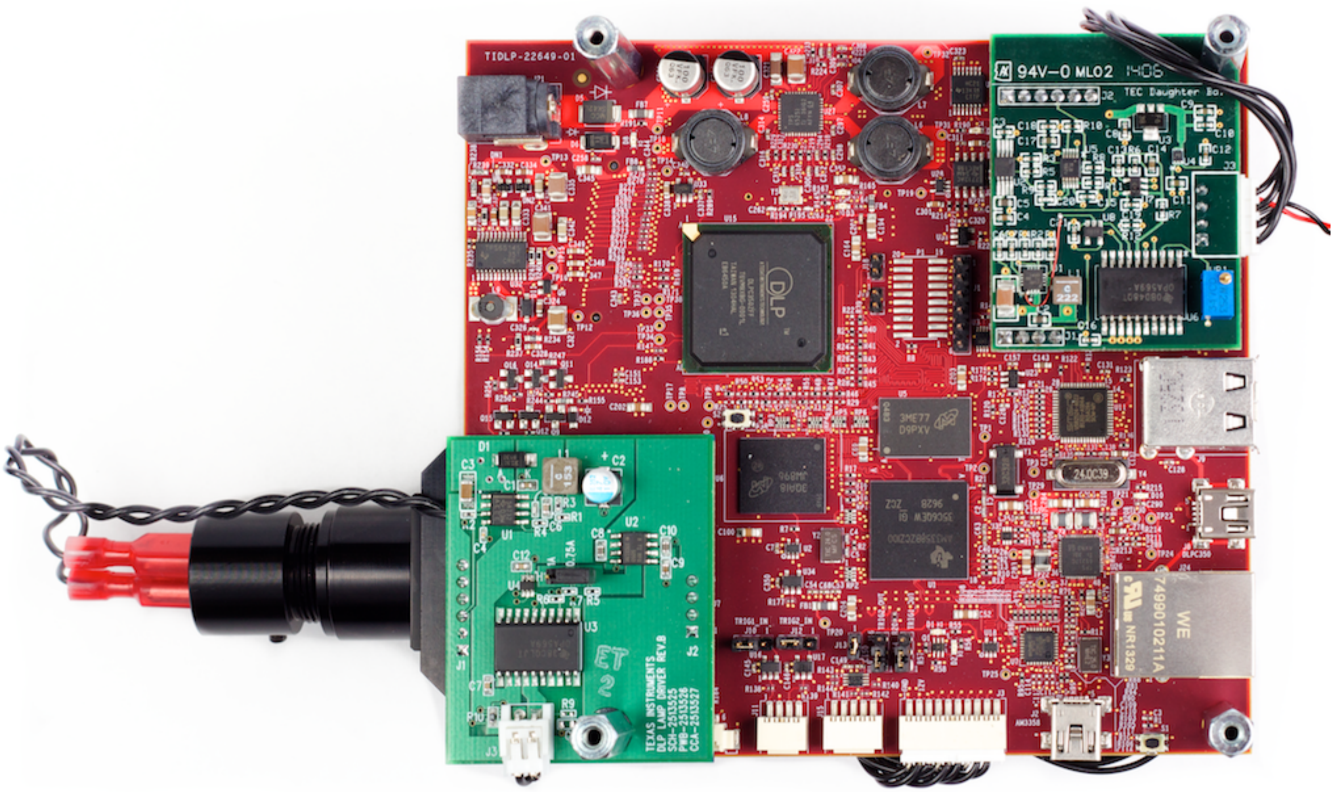


Figure 1-6. DLP NIRscan Electronics

The DLP NIRscan electronics contain many devices by TI, which are critical to the design and performance of the DLP NIRscan EVM (see Table 1-2).

Table 1-2. DLP NIRscan Electronics

Electronics	Device Number	Description
DLP chipset	DLPC350	Controller for the DLP4500 family of DMDs
	DLPC4500NIR	DMD
Embedded processor	AM3358	Sitara processor
Analog chain for detector	ADS1255	24-bit, 30 kSPS very-low noise delta-sigma ADC
	OPA2376	Precision, low noise, low quiescent current operation amplifier
Analog chain for TEC driver and lamp driver	OPA569	Power operational amplifier, output signal swings within 200 mV of rails at 2-A output
	INA330	Thermistor signal amplifier for temperature control
	OPA340	Micro operational amplifier for PID control of TEC driver
Power management	TPS65217C	Single-chip PMIC for battery-powered systems for AM3358, DDR3
	TPS65145	4-channel LCD bias with fully-integrated positive charge pump, 3.3-V LDO controller for DLP4500NIR power
	TPS73025	Single output LDO, 200 mA, fixed (2.5 V), high PSRR, low noise for DLP4500NIR power
	TPS65251	PMU with three DC-to-DC converters, up to 18-Vin for DLPC350 power
	TPS79718	Single output LDO, 50 mA, fixed (1.8 V), low quiescent current, Powergood out for DLPC350 power
	TLV61230	5-V supply for USB and input to TPS65217
	TLV61230	3.3-V supply
	REF5025	Low noise, very-low drift, precision voltage reference for TEC and ADC references
	TPS71750	5-V analog supply for ADC and TEC
	TPS71733	3.3-V analog supply for ADC
ESD protection	TPD4S012	4-channel USB ESD solution with power clamp

1.3 Other Items Needed for Operation

The DLP NIRscan EVM spectrometer is a flexible, ready-to-use EVM. However, the DLP NIRscan 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: 3 A
  - Maximum current: 5 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
- External laptop, desktop, or personal computer

1.4 DLP NIRscan Connections

Figure 1-7 and Figure 1-8 depict the connectors with their respective locations. Note that no cables, nor power supply are included with the unit. Only connection 8 and connection 14 or 7 are required for typical operation. All of the connections are listed for completeness in Table 1-3.

Table 1-3. Connection Descriptions

Connection	Type	Description
1	DLPC350 I^2C bus	Should not be used while the Sitara processor is controlling the DLPC350.
2	Fan power	This is the power output from the spectro board to power the fan.
3	TEC control cable	This connector is used to connect the TEC driver board to the detector board to drive the detector TEC and read back the thermistor value from the detector.
4	Micro-SD card slot	The micro-SD card slot is used for future DLP NIRscan software upgrades.
5	USB connectors	There are two USB expansion connections in connector 5. These connections can be used for most USB-compatible applications, such as USB memory storage, USB WLAN, or Bluetooth applications. The software to support these expansion features is not included in the DLP NIRscan.
6	Mini-USB interface to the DLPC350	This USB connection allows the DLP LightCrafter4500 GUI to access the DLPC350 or to control the DLPC350 through an external USB-capable microcontroller.
7	Ethernet RJ45	The Ethernet interface to the Sitara processor can be used instead of the Ethernet-over-USB connection 14. As of software release v1.0, to use the ethernet connection requires knowledge of the IP address assigned to the DLP NIRscan EVM at power-up. If a static IP address cannot be assigned, TI recommends using connection 14.
8	Power connector	Use a power supply with a 12-V DC output with 3- to 5-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.
9	Lamp power	This is the connector from the lamp driver board to the tungsten-halogen lamp.
10	JTAG interface for the DLPC350	
11	External trigger input connector	Supports two trigger input signals for DMD pattern synchronization.
12	External trigger output connector	Supports two trigger output signals. These are jumper configurable: • With jumper J13 installed, the output triggers are referenced to internal 3.3 V with up to 100 mA available at the external connector. • Without J13 installed, the triggers are reference to an externally supplied 1.8- to 5-V input.
13	ADC converter SPI bus	This is the data interface to the ADS1255 ADC.
14	Mini-USB to Sitara	This is the main method of connecting a laptop, desktop, or PC to the DLP NIRscan. The supported protocol is ethernet-over-USB and requires the RNDIS driver on the host PC.
15	S1	Pressing this switch resets the DLP NIRscan to its power-up condition.

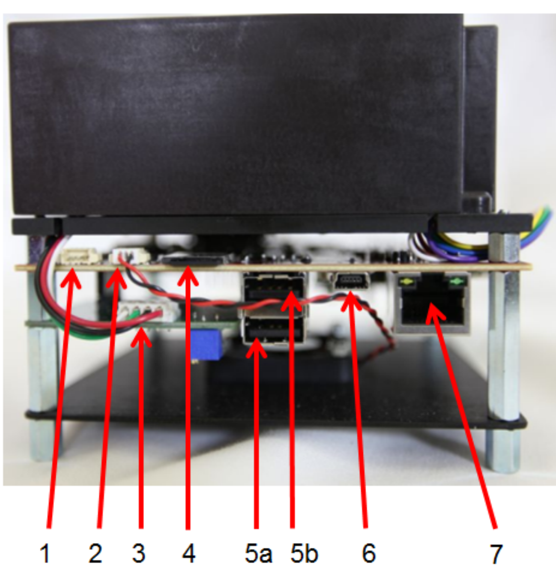


Figure 1-7. DLP NIRscan EVM Connectors (Backside View)

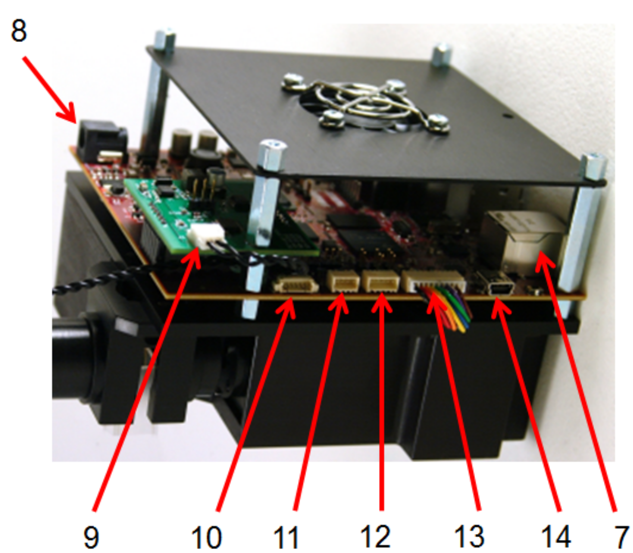


Figure 1-8. DLP NIRscan Connectors (Upside-Down Side View)

1.5 DLP NIRscan EVM Jumpers

The DLP NIRscan EVM has jumpers and a variable resistor to provide flexible board control options. This section lists the jumpers on the DLP NIRscan spectro board. Figure 1-9 depicts the locations of these jumpers. These jumpers require a 2-mm jumper, such as Sullins Connector Solutions® SPN02SYBN-RC, Digi-Key part number S3404-ND.

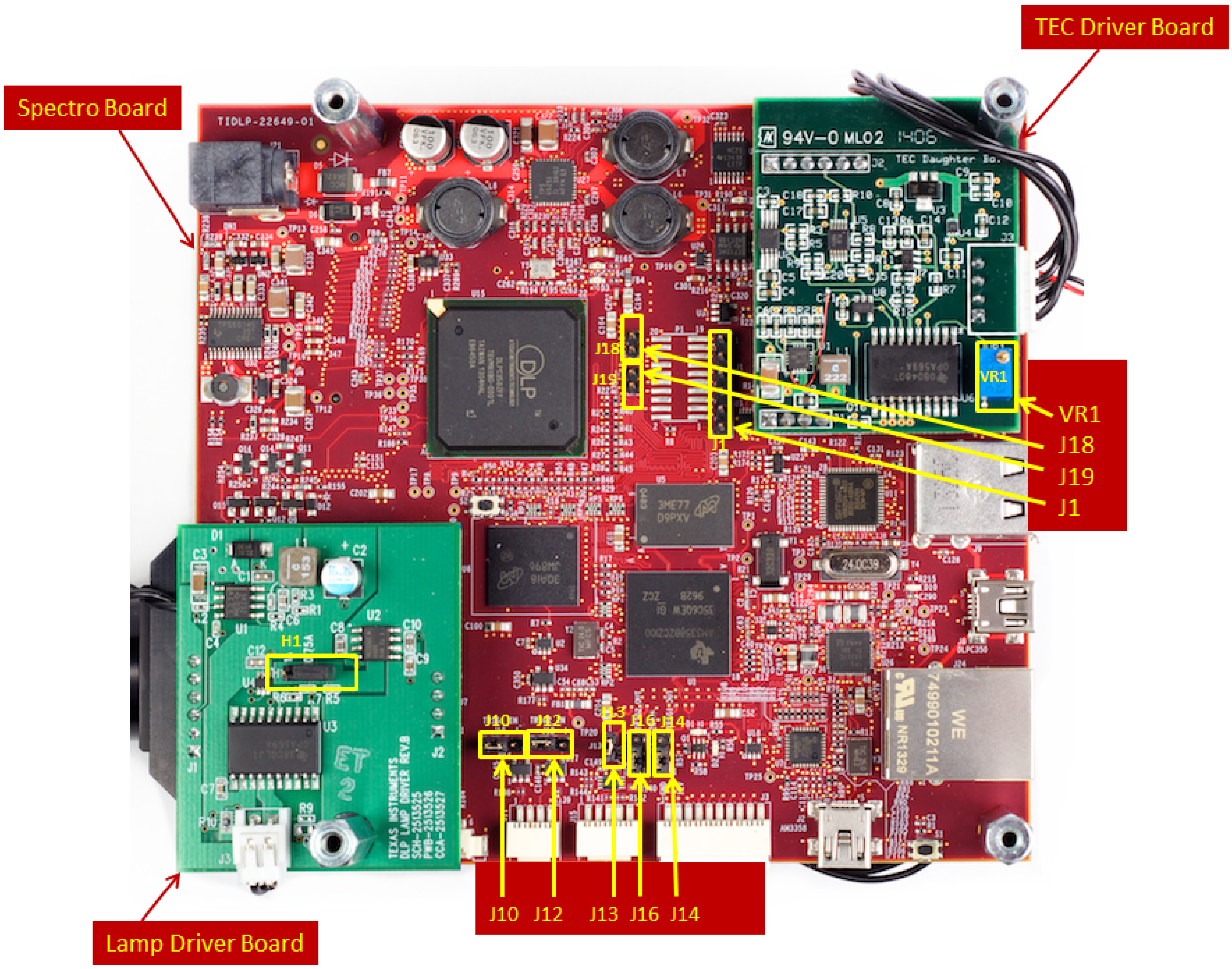


Figure 1-9. DLP NIRscan Jumper Locations

TEC Driver Board

- VR1 – This variable resistor sets the maximum current provided to the TEC of the detector. This can determine at what ambient temperatures the detector will remain cooled to approximately –40ºC. This resistance is set at the factory and should not be changed unless a different detector or ambient temperature is used.

Lamp Driver Board

- H1 – sets the current to the lamp.
  - Terminals 1 and 2 = 1 A
  - Terminals 2 and 3 = 0.75 A (default)

Spectro Board

- J1 – Sitara UART0 port. Connect to this port for debug messages and Sitara debug control.
  - Terminal 1 = GND

  - Terminal 2 = NC
  - Terminal 3 = NC
  - Terminal 4 = UART_RX
  - Terminal 5 = UART_TX
  - Terminal 6 = NC
- J10 – Trigger In 1
  - Terminals 1 and 2 = External connector triggers the DLPC350
  - Terminals 2 and 3 = Sitara triggers the DLPC350 (default)
- J12 – Trigger In 2
  - Terminals 1 and 2 = External connector triggers the DLPC350
  - Terminals 2 and 3 = Sitara triggers the DLPC350 (default)
- J14 – Trigger out 1
  - Terminals 1 and 2 = DLPC350 generated trigger out 1 (default)
  - Terminals 2 and 3 = Sitara generated trigger out 1
- J16 – Trigger out 2
  - Terminals 1 and 2 = DLPC350 generated trigger out 2 (default)
  - Terminals 2 and 3 = Sitara generated trigger out 2
- J13 – Power selector for trigger out voltage levels
  - Jumper installed = Trigger outputs on J15 use internal 3.3-VDC levels (default)
  - Jumper open = Trigger outputs on J15 use voltage levels supplied J15 terminal-1
  - Note: Externally supplied voltage levels need to be 1.8, 3.3, or 5 V
- J18 – DLPC350 hold bootloader
  - Jumper open = Normal operation (default)
  - Jump across this header to hold the DLPC350 in bootloader mode. This hold is only needed if the DLPC350 firmware becomes corrupted and needs to be reprogrammed through the JTAG boundary scan or USB (atypical).
- J19 – DLPC350 I^2C address select
  - Jumper installed sets I^2C address to 0×3A and USB device serial number to LCR3
  - Jumper not installed sets I^2C address to 0×34 and USB device serial number to LCR2 (default)

Quick Start

This chapter details the steps to power-up and use the DLP NIRscan EVM spectrometer.

2.1 Power-Up the DLP NIRscan EVM

The DLP NIRscan is ready to use, out of the box. Follow these steps to power up, connect the EVM to a computer, and access the home screen.

1. Connect a 12-V DC power supply to the input power supply connector.
2. An LED next to the power connector on the spectro board lights up green. The fan starts and the DLPC350 and Sitara processor start booting. After 5 to 10 s, the DLPC350 is confirmed to be running its firmware if green LED D3 (in the middle of the spectro board) starts flashing a heartbeat (approximately one flash per second). A blue LED next to the Sitara Micro-USB connector will also light to show the Sitara power supplies are up.
3. The EVM's Sitara processor runs a webserver, which provides display information to the user through an HTML browser such as Mozilla Firefox®, Google™ browser, Safari®, or Internet Explorer®. Connect the USB port of the computer with the browser to the EVM through the micro-USB connection at location 14.
4. Many computers ship with RNDIS drivers installed, which are required to use Ethernet-over-USB. After plugging-in the micro-USB cable in step 3, if there is no RNDIS driver installed on the computer, the software typically prompts the user before searching for the driver. After the RNDIS driver is installed, then start the browser software of your choice.
5. Type the following location into the URL window at the top of the browser screen: ***http://192.168.0.10***. The first time the cable is connected on a PC, the DLP NIRscan enumerates. If the browser does not connect within 30 seconds, or the browser times out, the user may need to refresh the browser once or twice to provide more time for the system to enumerate, load the RNDIS driver, and register its IP address with the host PC.
6. When connected to the DLP NIRscan, the NIRscan Home Screen should display in the browser window (see Figure 2-1).

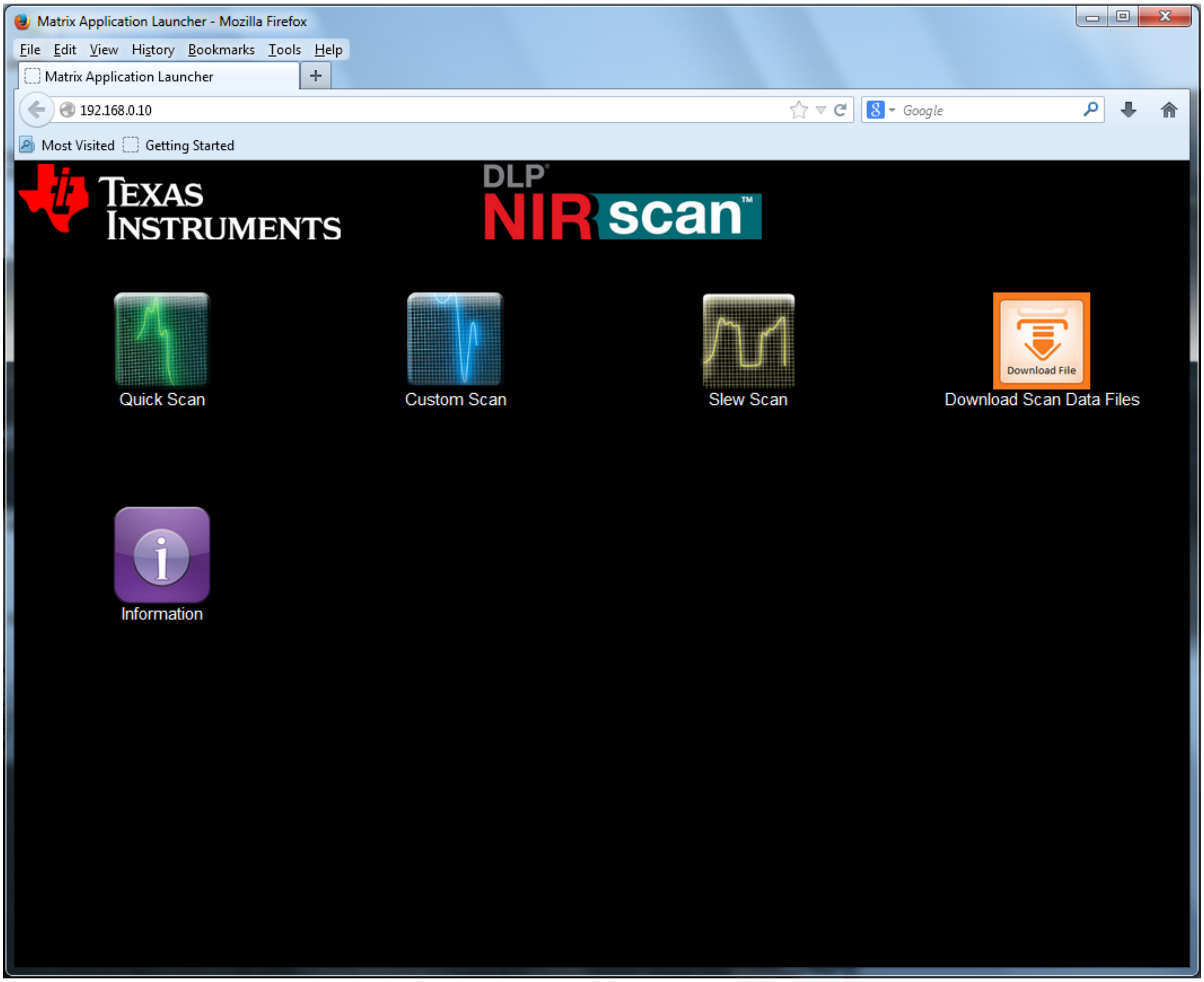


Figure 2-1. DLP NIRscan Homepage

Operating the DLP NIRscan EVM

This chapter introduces the software executing within the DLP NIRscan EVM. The DLP NIRscan Homepage has five icons:

- **Quick Scan** – Scans can be made quickly and effortlessly with fixed configuration parameters.
- **Custom Scan** – Users can interact with certain settings to customize scans and access raw scan data.
- **Slew Scan** – Users can customize the scan for distinct regions for select wavelengths, resolutions, and integration times.
- **Download Files** – Users can download the spectral and/or raw data files for scans to their local machine.
- **Information** – This icon provides the DLP NIRscan EVM software version information and links to DLP NIRscan information located on www.ti.com

3.1 Quick Scan Mode

From the NIRscan Home screen, clicking the **Quick Scan** icon takes the user to the Quick Scan screen (see Figure 3-1).

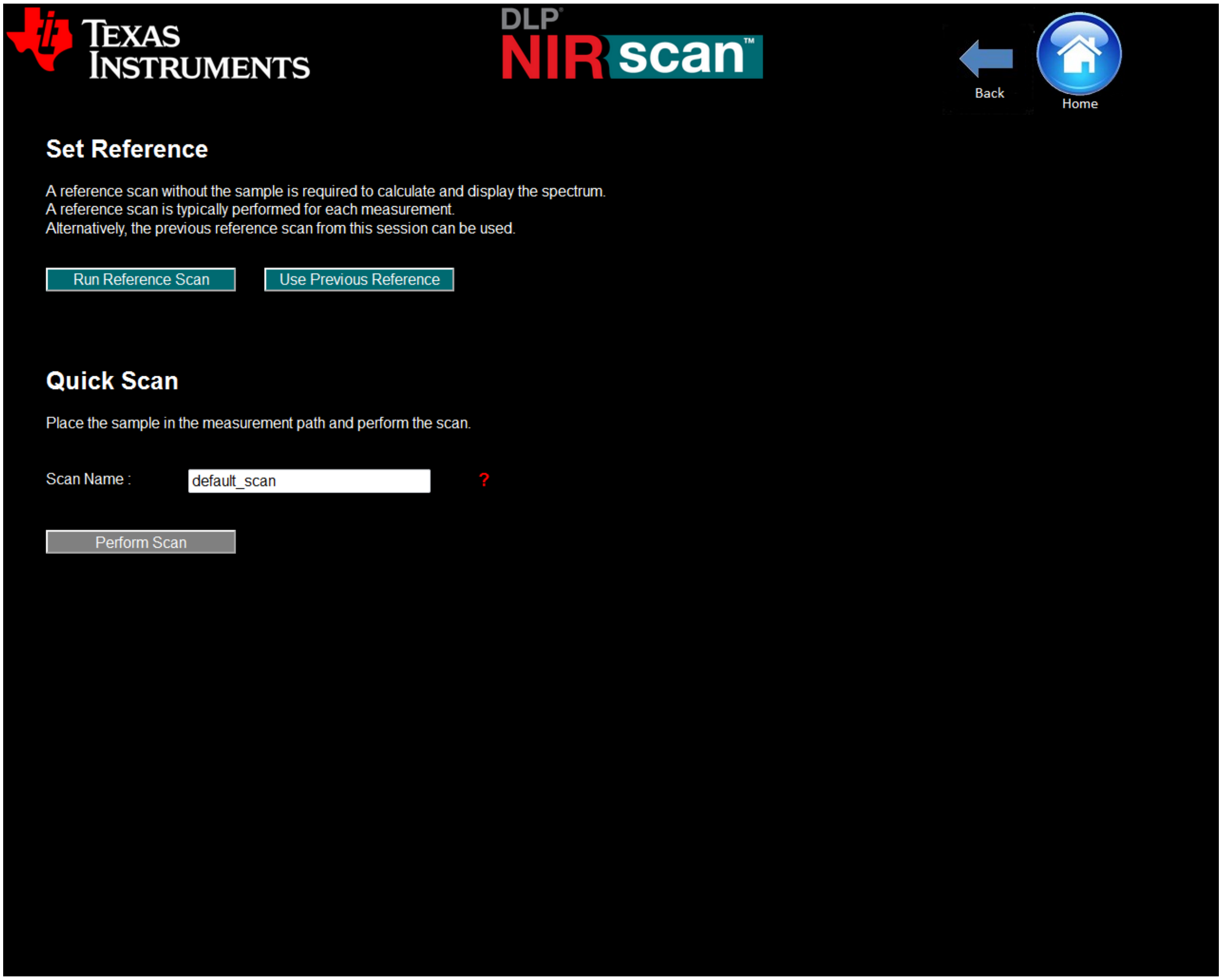


Figure 3-1. Quick Scan Screen

The steps to take a Quick Scan are:

1. Set the reference by clicking either **Run Reference Scan** or **Use Previous Reference**.
   - **Run Reference Scan** causes the spectrometer to scan the reference sample.
   - **Use Previous Reference** does not re-scan the reference, but uses reference data from the last Quick Scan reference.
   - If measuring a liquid sample in a cuvette, then the reference scan is typically taken using an empty cuvette in the sample holder. This reference scan allows the absorbance of the cuvette material to be negated when the absorbance of the liquid sample material is calculated.
   - For measurement of solid transmissive materials such as sheet plastic, the sample holder should be left empty during the reference scan.
2. Users can change the scan name or use the default name. The scan name will become part of the resulting scans filenames, which can be downloaded from the DLP NIRscan EVM once scans are complete.
3. Load the cuvette with the liquid sample or insert the sheet plastic into the sample holder.

4. Select the **Perform Scan** button. The DLP NIRscan will then scan the sample, calculate the sample material absorbance, and display the absorbance in graphical format on the next screen. Figure 3-2 shows an example of this screen.

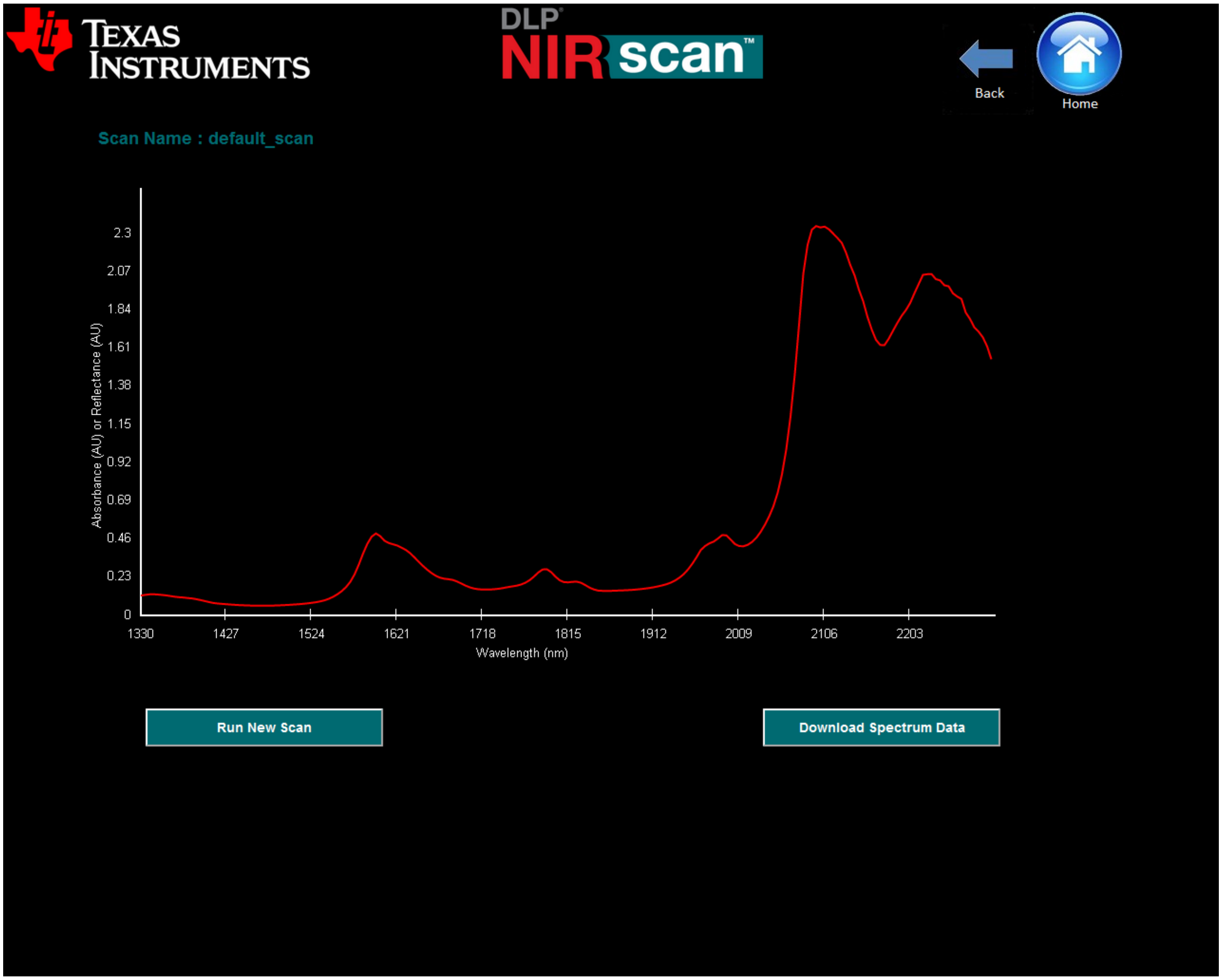


Figure 3-2. Example Quick Scan

The graphical representation shows the absorbance spectrum of the material, with absorbance units (AU) on the y-axis and sampled wavelength on the x-axis.

1. To run another Quick Scan, insert a new sample in the sample holder and select the **Run New Scan** button. The new scan is taken, the new absorbance spectrum is calculated (using the previous reference), and the new spectrum re-plots to the screen all with a single click. This action can be performed repeatedly. The filename provided on the previous Quick Scan screen is incremented with each sample run so that sample data files can be distinguished from each other.
2. To save the spectrum data to a local machine, click the **Download Spectrum Data** button. This action prompts the user to open the .csv file in excel (if available on the users machine) or to save the file locally. The file format imports into excel as shown in Figure 3-3.

Method:	Line Scan
Host Date-Time:	31/3/2014 @ 9:42:58
Sample Name:	default_scan
Spectral Range Start (nm):	1350
Spectral Range End (nm):	2450
Number of Wavelength Points:	200
Digital Resolution (nm):	5.5
Number of Scans to Average:	1
Total Measurement Time (ms):	300

Wavelength (nm)	Absorbance (AU)	Reference Signal (unitless)	Sample Signal (unitless)
1353.33	0.0829	47880	39560
1359.34	0.0891	42841	34896
1365.35	0.0936	47774	38514
1371.36	0.0962	42989	34448
1377.36	0.0966	48172	38565

Figure 3-3. Example Quick Scan Spectrum Data

Note that the header in the download file contains many important aspects of the scan, including:

1. Method: This defaults to linescan mode at this time, referencing how the sample is taken by scanning vertical lines across the DMD, each line representing a specific wavelength.
2. Host Date-Time: This is the date (browser date) and time the scan was taken.
3. Sample name: this is the scan name entered on the first Quick Scan screen. If this has not been changed, the sample name will default to default_scan.
4. Spectral Range Start: always 1350 nm for Quick Scan mode
5. Spectral Range Stop: always 2450 nm for Quick Scan mode
6. Number of wavelength points: 200 for Quick Scan mode
7. Digital resolution: 5.5 nm for Quick Scan mode
8. Number of scans to average: 1 scan for Quick Scan mode
9. Total measurement time: The time taken to scan all wavelengths
10. The rest of the file is the actual data and includes:
    - Wavelength
    - Calculated spectrum value for each wavelength
    - Average reference ADC value for each wavelength
    - Average sample ADC value for each wavelength

After the data is saved locally on the machine running the browser, the user can return to the Quick Scan screen.

3.2 Custom Scan Mode

From the NIRscan Home screen, clicking the **Custom Scan** icon takes the user to the Custom Scan screen (see Figure 3-4).

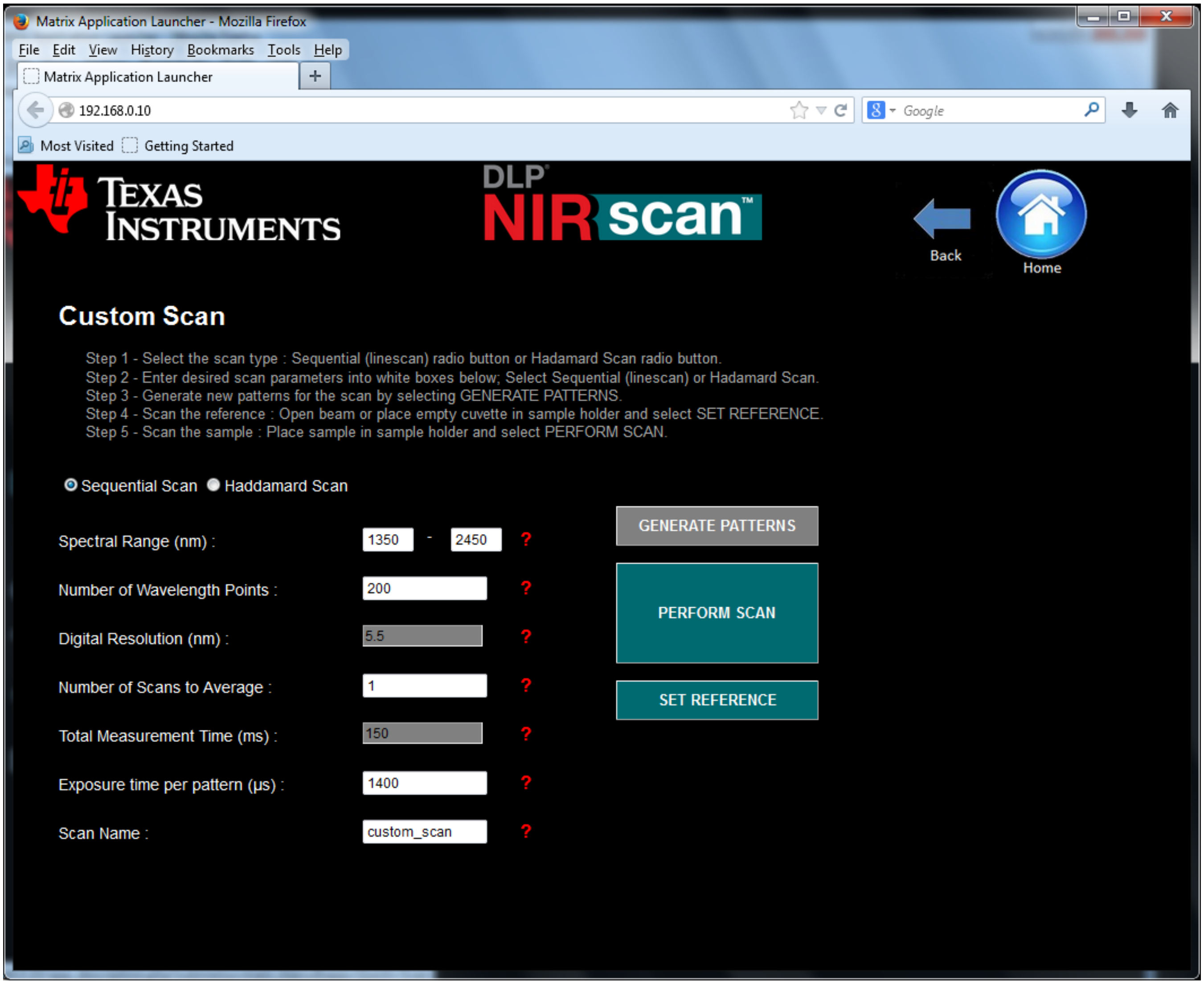


Figure 3-4. Custom Scan Screen

The Custom Scan mode allows more flexibility than the Quick Scan mode by allowing the user to change the configuration parameters for the scan. The parameters for the Custom Scan mode are:

- **Spectral range**: for faster scan times, sub-ranges of the total 1350- to 2450-nm range can be used. The smaller the spectral range entered, the faster the scan. For a custom wavelength range, the smaller wavelength must be located on the left and the larger on the right. All values must be between 1350 nm and 2450 nm.
- **Number of wavelength points**: This number defines how many wavelengths the spectral range will be divided into. The minimum is 3 and the maximum is 1100. The included optical system has an optical resolution of ≤12nm. Increasing the number of wavelength points such that the computed digital resolution is much less than 12nm will reduce system throughput without much of an optical resolution advantage.
- **Digital resolution**: This is an informational output field for the user. The calculated resolution is the wavelength range divided by the number of wavelength points.
- **Number of scans to average**: This is the number of times the entire wavelength range is repeatedly sampled. If the number in this field is 1, then the wavelength range entered is scanned only one time. If the number 2 is entered, the wavelength range is scanned twice, one complete scan after another. The average spectrum data for each wavelength is averaged with the data for the same wavelength on subsequent scans.

- **Total measurement time**: The length of time needed to run the entire scan across all wavelengths as entered.
- **Scan name**: This field allows changing the scan name to reflect something more specific to the user, that is, like the material being scanned.

In the Custom Scan mode, the user must select actions which have green buttons. Clicking on gray-colored buttons is ignored. To run the Custom Scan, perform the following tasks:

1. Accept the values in the custom parameter fields or enter your custom parameters based on the previous descriptions.
2. If the user accepts the default parameters, then the **Generate Patterns** button remains gray. If the user changes the parameters, the **Generate Patterns** button turns green.
3. If the **Generate Patterns** button is green, click this button. When selected, the DLP NIRscan calculates the new DMD patterns for the user-selected inputs, generates the patterns, applies the hardware-specific calibration, and saves the patterns in memory for the scan to commence. This step is complete when the **Set Reference** button turns green and the message *Patterns Generated - Set New Reference!* message appears.
4. Select the **Set Reference** button.
   - To measure a liquid sample in a cuvette, first run the reference scan with an empty cuvette in the sample holder. This allows the absorbance of the cuvette material to be negated when the absorbance of the material is calculated.
   - When measuring a solid transmissive material such as a plastic by inserting the plastic into the sample holder, the sample holder should be left empty during the reference scan.
5. Insert the sample in the sample holder (with or without cuvette).
6. Select the **Perform Scan** button. The DLP NIRscan then scans the sample, calculates the sample material absorbance, and displays the absorbance in graphical format on the next screen. Figure 3-5 shows an example of this screen.

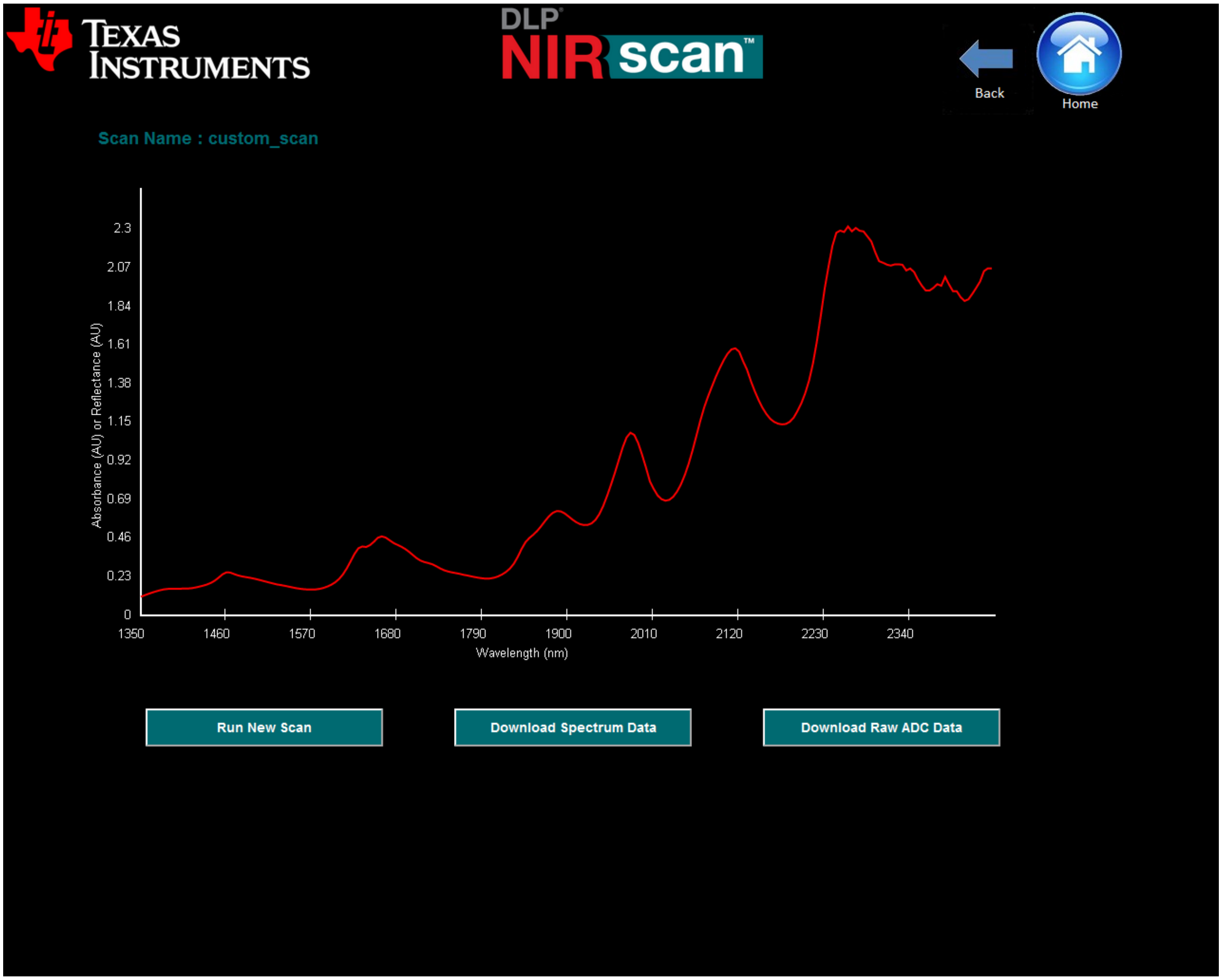


Figure 3-5. Example Custom Scan

The graphical representation shows the absorbance spectrum of the material, with absorbance units (AU) on the y-axis and sampled wavelength on the x-axis.

1. To run another scan, insert a new sample (or use the same sample, to re-sample the same material), and select the **Run New Scan** button. The new scan runs, the new absorbance spectrum calculates (using the previous reference), and the new spectrum plots all with one button click. This action can be performed repeatedly. Note that the scan name provided on the previous Custom Scan screen increments with each sample run.
2. To save the spectrum data to a local machine, click the **Download Spectrum Data** button. This action prompts the user to open the .csv file in excel (if available on the users machine) or to save the file locally. The file format imports into excel as shown in Figure 3-6.

Method:	Line Scan
Host Date-Time:	31/3/2014 @ 9:42:58
Sample Name:	default_scan
Spectral Range Start (nm):	1350
Spectral Range End (nm):	2450
Number of Wavelength Points:	200
Digital Resolution (nm):	5.5
Number of Scans to Average:	1
Total Measurement Time (ms):	300

Wavelength (nm)	Absorbance (AU)	Reference Signal (unitless)	Sample Signal (unitless)
1353.33	0.0829	47880	39560
1359.34	0.0891	42841	34896
1365.35	0.0936	47774	38514
1371.36	0.0962	42989	34448
1377.36	0.0966	48172	38565

Figure 3-6. Example Custom Scan Spectral Data

Note that the header in the download file contains many important aspects of the scan, including:

1. Method: This defaults to linescan mode at this time, referencing how the sample is taken by scanning vertical lines across the DMD, each line representing a specific wavelength.
2. Host Date-Time: This is the date (browser date) and time the scan was taken.
3. Sample Name: This is the scan name entered on the first Custom Scan screen. If this has not been changed, the sample name will default to default_scan.
4. Spectral Range Start: This reflects the lower scan limit entered on the Custom Scan screen.
5. Spectral Range End: This reflects the upper scan limit entered on the Custom Scan screen.
6. Number of Wavelength Points: This reflects the number entered on the Custom Scan screen.
7. Digital Resolution: This reflects the number calculated on the Custom Scan screen.
8. Number of Scans to Average: This reflects the number entered on the Custom Scan screen.
9. Total Measurement Time: This reflects the number calculated on the previous screen.
10. The rest of the file is the actual data and includes:
    - Wavelength
    - Calculated absorbance value for each wavelength
    - Average reference ADC value for each wavelength
    - Average sample ADC value for each wavelength

After the data is saved locally on the machine running the browser, the user can return to the Custom Scan screen.

Download Raw ADC Data: In the Custom Scan mode, there is another button located beneath the plotted absorbance spectrum labeled **Download Raw ADC Data**. Whereas the **Download Spectrum** button provides averaged reference and sample data values, there are potentially cases where a user may want to download all the data points sampled during the scan. To save the raw data to a local machine, click the **Download Raw ADC Data** button. This action prompts the user to open the .csv file in excel (if available on the users machine) or to save the file locally. The file format imports into excel as shown in Figure 3-7.

Method:	Line Scan	
Host Date-Time:	31/3/2014 @ 9:45:28	
Sample Name:	custom_scan	
Spectral Range Start (nm):	1350	
Spectral Range End (nm):	2450	
Number of Wavelength Points:	200	
Digital Resolution (nm):	5.5	
Number of Scans to Average:	1	
Total Measurement Time (ms):	292.6	

Pattern	Reference ADC Readings (unitless)	Sample ADC Readings (unitless)
0	23361	14162
0	23346	14169
0	23353	14213
0	23347	14257
0	23368	14243
0	23361	14221
0	23360	14238
0	23377	14209
0	23400	14174

Figure 3-7. Example Custom Scan Raw Data

Note that the header in the download file contains many important aspects of the scan, including:

1. Method: This defaults to linescan mode at this time, referencing how the sample is taken by scanning vertical lines across the DMD, each line representing a specific wavelength.
2. Host Date-Time: This is the date (browser date) and time the scan was taken.
3. Sample Name: This is the scan name entered on the first Custom Scan screen. If this has not been changed, sample name will default to default_scan.
4. Spectral Range Start: This reflects the lower scan limit entered on the previous screen
5. Spectral Range Stop: This reflects the upper scan limit entered on the previous screen
6. Number of Wavelength Points: This reflects the number entered on the previous screen
7. Digital Resolution: This reflects the number calculated on the previous screen
8. Number of Scans to Average: This reflects the number entered on the previous screen.
9. Total Measurement Time: This reflects the number calculated on the previous screen
10. The rest of the file is the actual raw data and includes:
    - DMD pattern number
    - Individual reference ADC data values for each pattern (wavelength)
    - Individual sample ADC data values for each pattern (wavelength)

After the data is saved locally on the machine running the browser, the user can return to the Custom Scan screen.

3.3 Slew Scan Mode

From the NIRscan Home screen, clicking the **Slew Scan** icon takes the user to the Slew Scan screen (see Figure 3-1).

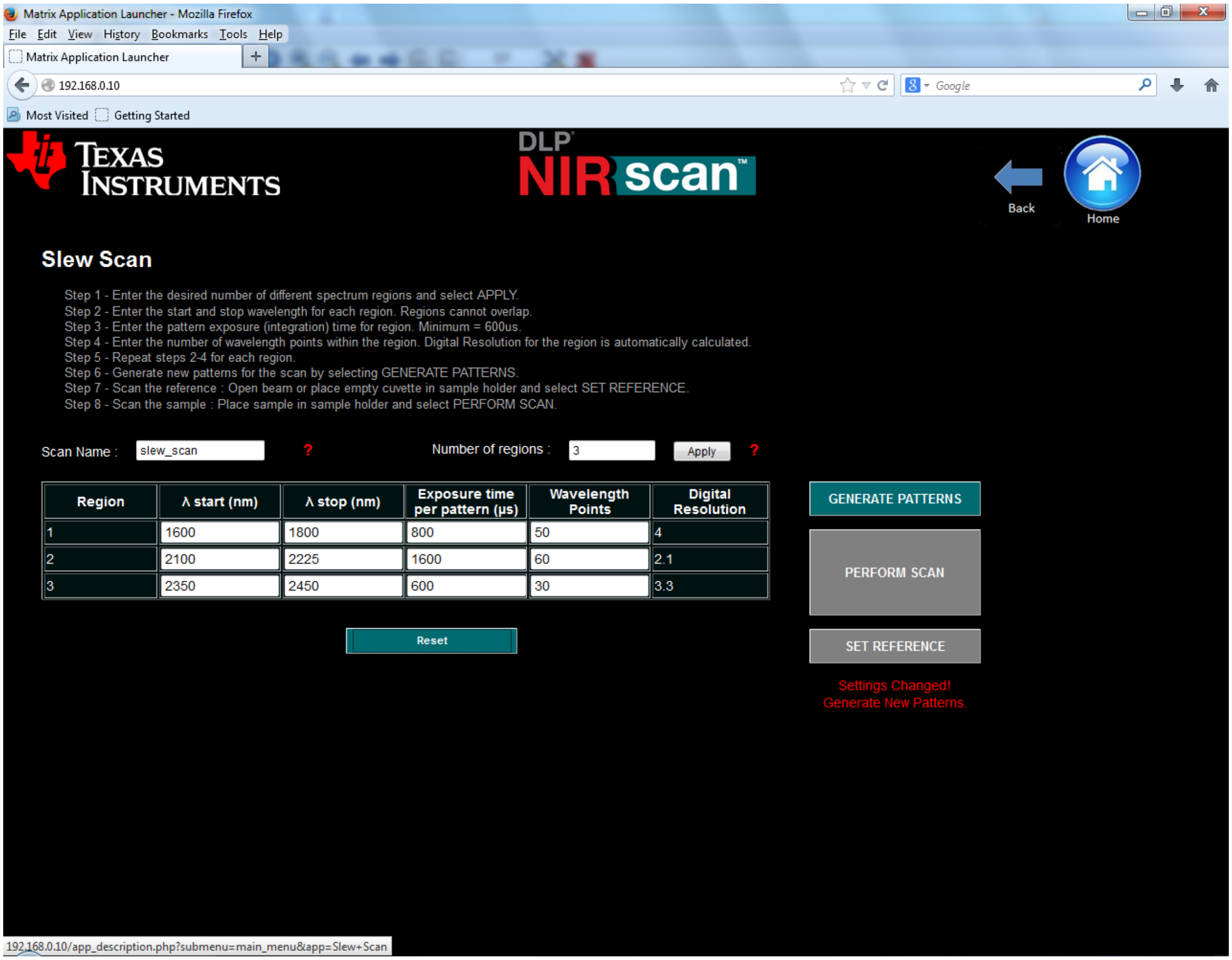


Figure 3-8. Slew Scan Screen

The Slew Scan screen provides users the ability to divide the 1350-2450nm spectral range into user defined regions, each region with its own spectral range, exposure (integration) times, and spectral resolutions. Non-overlapping regions from 1 to 10 can be defined. This provides unique scan methods which enable the following use cases:

- **Wavelength Skipping:** Sometimes, the entire spectral range need not be scanned for users to identify specific molecules within a sample. Scanning a subset of defined spectral regions of the spectral range is all that is needed. In this case, uninteresting regions of the spectrum can be omitted in the scan by specifying only the spectral regions of interest. Gaps between segments are allowed. Figure 3-8 shows a Slew Scan configuration example showing how spectral regions of interest are entered in the table - all other areas of the spectrum not entered are ignored, thereby making the scan much shorter yet still capable of detecting the presence (or absence) of important molecules.
- **Variable Resolution:** Based on the spectrum expected for a given substance, there may be regions of the spectrum where high digital resolution is needed, with less interesting areas requiring less resolution. Each region in the configuration table can be configured to have different resolutions. Lower resolutions for areas of little (expected) detail help speed up scan times.
- **Variable Integration:** Exposure (Integration) Times for each defined region can be increased or decreased to meet user specific Signal-to-Noise Ratio (SNR) requirements. In regions which have high absorbance, longer exposure times (averaging) may be needed to improve SNR, and in regions of low absorbance and possibly little importance, shorter exposure times are more than adequate for deterministic results. By decreasing exposure times for these uninteresting regions, it helps to speed

up overall scan times.

Below are the steps to setup and execute a Slew Scan. This example uses 3 regions which are not contiguous, have different exposure times per pattern in each region, and different digital resolutions for each region. The configuration is located above in Figure 3-8. Graphical output results are shown below in Figure 3-9

1. Determine the number of distinct spectral segments required and enter that number in the ***Number of Regions*** box. Now click the ***Apply*** button and the entry table expands or contracts to provide one row for each Region. Now the user can enter the desired configuration settings for each of the desired regions:
   - **Lambda Start (nm)**: is the starting wavelength for the region N. The starting wavelength must be ≥1350 and must be
     > the Region (N-1)'s Lambda Stop value.
   - **Lambda Stop (nm)**: is the stopping wavelength for the region N. The stopping wavelength must be > the region N Lambda start value, and must be ≤2450.
   - **Exposure time per pattern (µs)**: The minimum Exposure time is 600 (µs). The [maximum allowed exposure time (µs/pattern)] × [the number of wavelength points] should be ≤1 second. The exposure time constraints are limited by NIRscan EVM software design - since the DLP patterns applied to the DMD are inherently programmable, customer systems can certainly implement much longer integration times for applications which require them.
   - **Wavelength Points**: The number of Wavelength Points defines the number of the patterns being applied to the DMD within this region only. ([Lambda stop - Lambda Start] / # Wavelength Points) = the Digital Resolution for which the DMD is programmed. Please note that Digital Resolutions is only one of the contributors to the true spectral resolution of a DLP based spectrometer. Please see the DLP Spectrometer Design Considerations for more information regarding spectrometer resolution as a function of DMD digital resolution, input slit width, and optical point spread function.
2. As in the other scan modes, the user can change the scan name, or leave the default name in place. This name will be embedded in the resulting filenames for imminent scans, which can be downloaded from the DLP NIRscan after the scans are complete.
3. As in the Custom Scan mode, whenever new configuration data is entered, or existing settings are modified, the NIRscan needs to generate new patterns defined by the new configuration data. The Generate Patterns button turns green when the configuration data changes to indicate new patterns are needed. The user should click the ***Generate Patterns*** button. This step is complete when the **Set Reference** button turns green and the message *Patterns Generated - Set New Reference!* message appears.
4. Now select the **Set Reference** button.
   - If planning to measure a liquid sample in a cuvette, first run the reference scan with an empty cuvette in the sample holder. This allows the absorbance of the cuvette material to be negated when the absorbance of the material is calculated.
   - When measuring a solid transmissive material such as sheet plastic by inserting the plastic into the sample holder, the sample holder should be left empty during the reference scan.
5. Insert the sample in the sample holder (with or without cuvette).
6. Select the **Perform Scan** button. The DLP NIRscan will scan the sample, calculate the sample material absorbance, and display the absorbance in graphical format on the next screen. Figure 3-5 shows an example of this output.

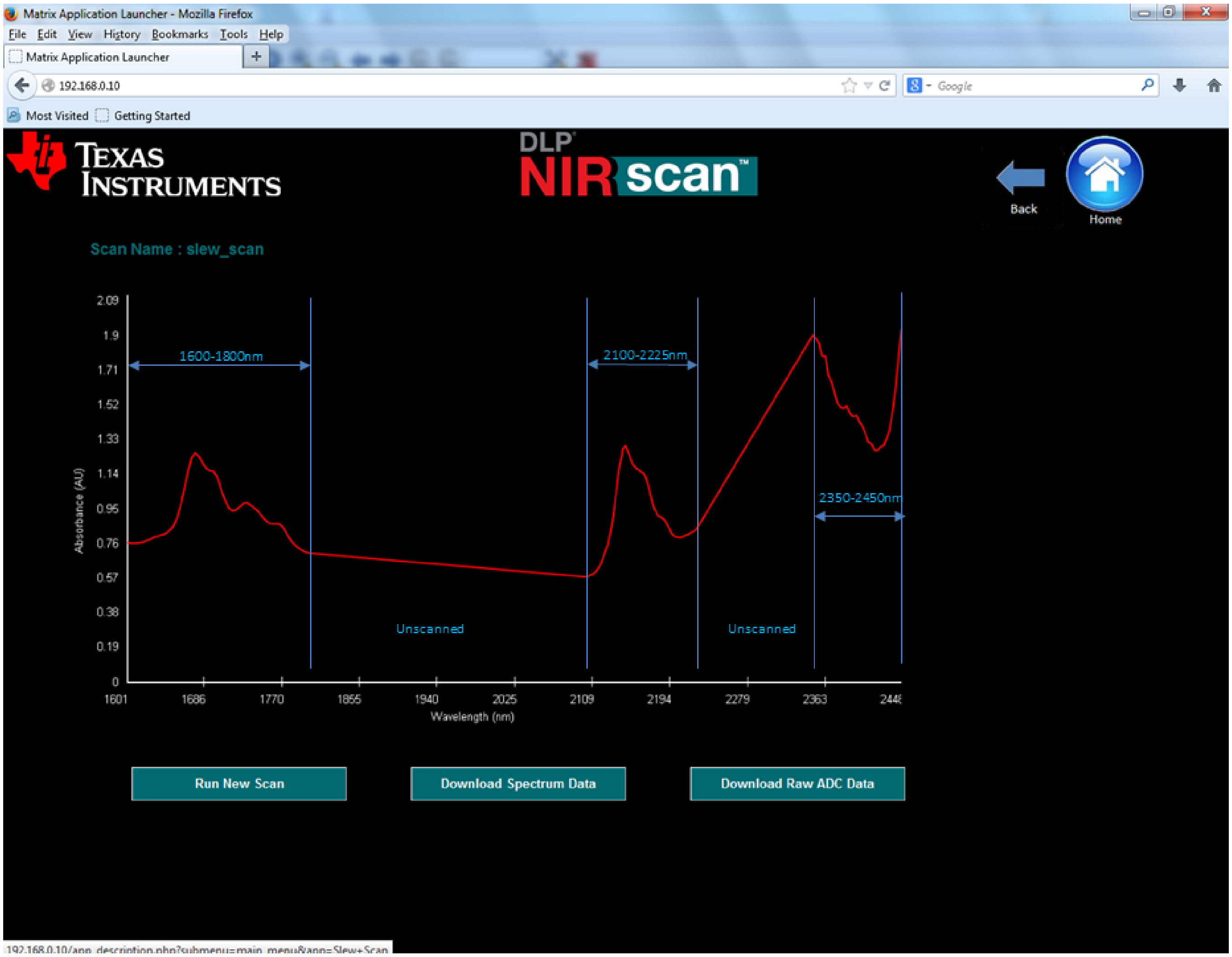


Figure 3-9. Eample Slew Scan

The graphical representation in Figure 3-9 shows the absorbance spectrum of the sampled material, with absorbance units (AU) on the y-axis and wavelength on the x-axis. The 3 regions of interest are highlighted in blue and the two regions not of interest are identified with the word "unscanned". Each scanned region is measured based on the configuration information supplied for that region. For unscanned spectral regions not configured in the configuration table, the graphical output shows a straight line from the last wavelength in region N to the first wavelength in region N+1.

1. To run another scan, insert the new sample and select the **Run New Scan** button. The new scan runs, the new absorbance spectrum calculates (using the previous reference), and the new spectrum plots all with one button click. This action can be performed repeatedly. The scan filename provided on the previous Slew Scan configuration screen increments with each sample run. Data files for these scans can then be downloaded to a local machine.
2. To save the spectrum data for the most recent scan to a local machine, click the **Download Spectrum Data** button. This action prompts the user to open the .csv file in excel (if available on the users machine) or to save the file locally. The file format provided for Slew Scan mode is very similar to the previously defined Custom Scan file format, except the file format will be identified as a Slew Scan and there will be breaks in the wavelength data for undefined scan regions.

3.4 File Download Icon

From the NIRscan Home screen, clicking on the **File Download Icon** on the DLP NIRscan Home screen will take the user to a screen where the user can select for download either spectrum data files or raw data files from previous scans. It is important to note that all scan files are cleared from the DLP NIRscan EVM memory when the unit is powered off or reset. (see Figure 3-10).

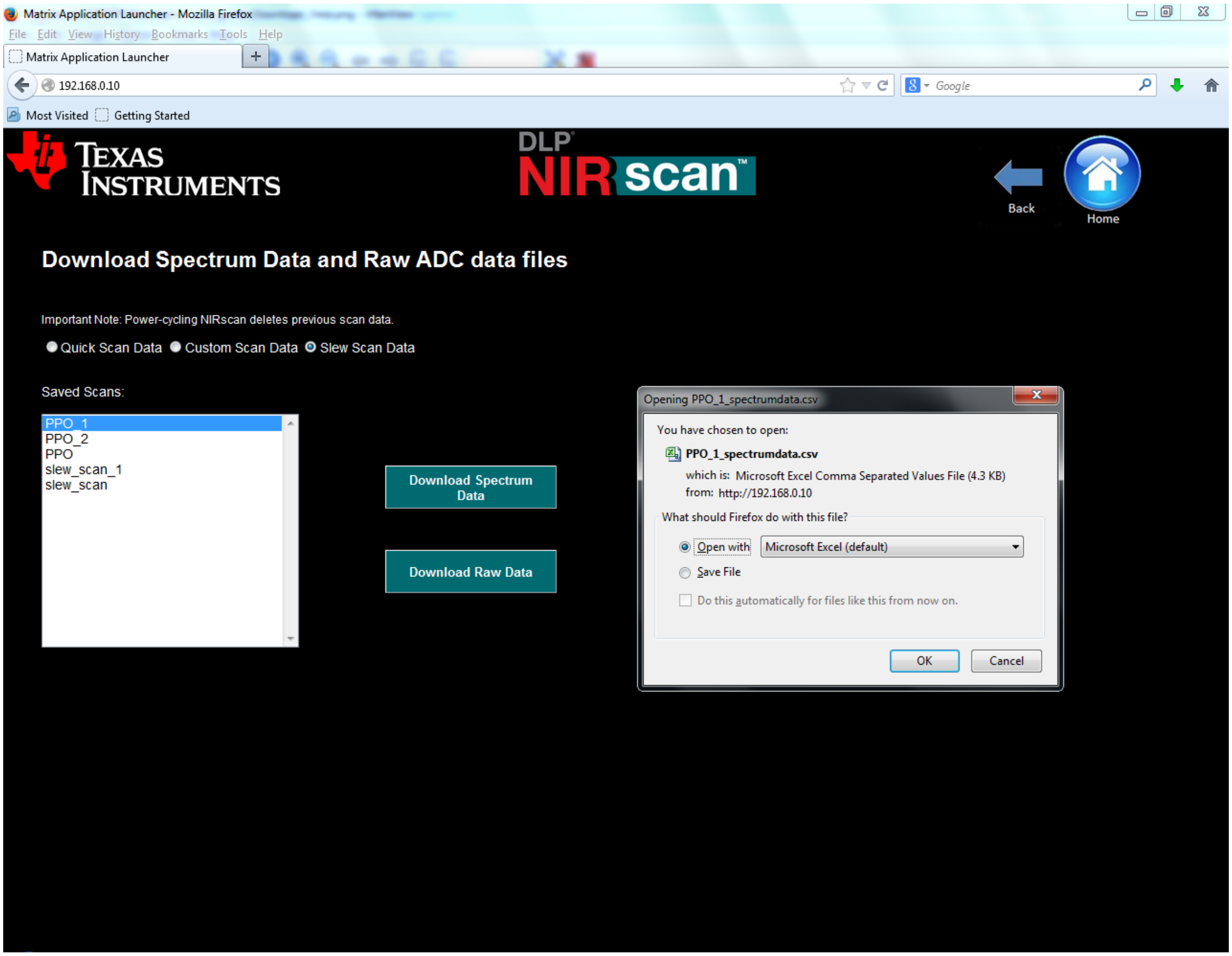


Figure 3-10. File Download Screen

The File Download Screen shows the files for all scans which have been captured on the NIRscan. The user must select the scan type for the data they are seeking to download by selecting either the Quick Scan button, the Custom Scan button, or the Slew Scan button. Once the scan type is selected, the user can select one file name per instance, and download the Spectrum data by selecting the Download Spectrum Data button, or the raw data by selecting the Download Raw Data button. A browser specific window will pop up asking the user to save or open the file. To download another file, the user must select a different file from the list and follow the same procedure.

3.5 System Information

From the NIRscan Home screen, clicking on the **Information Icon** on the DLP NIRscan Home screen will take the use to the following Information screen (see Figure 3-10).

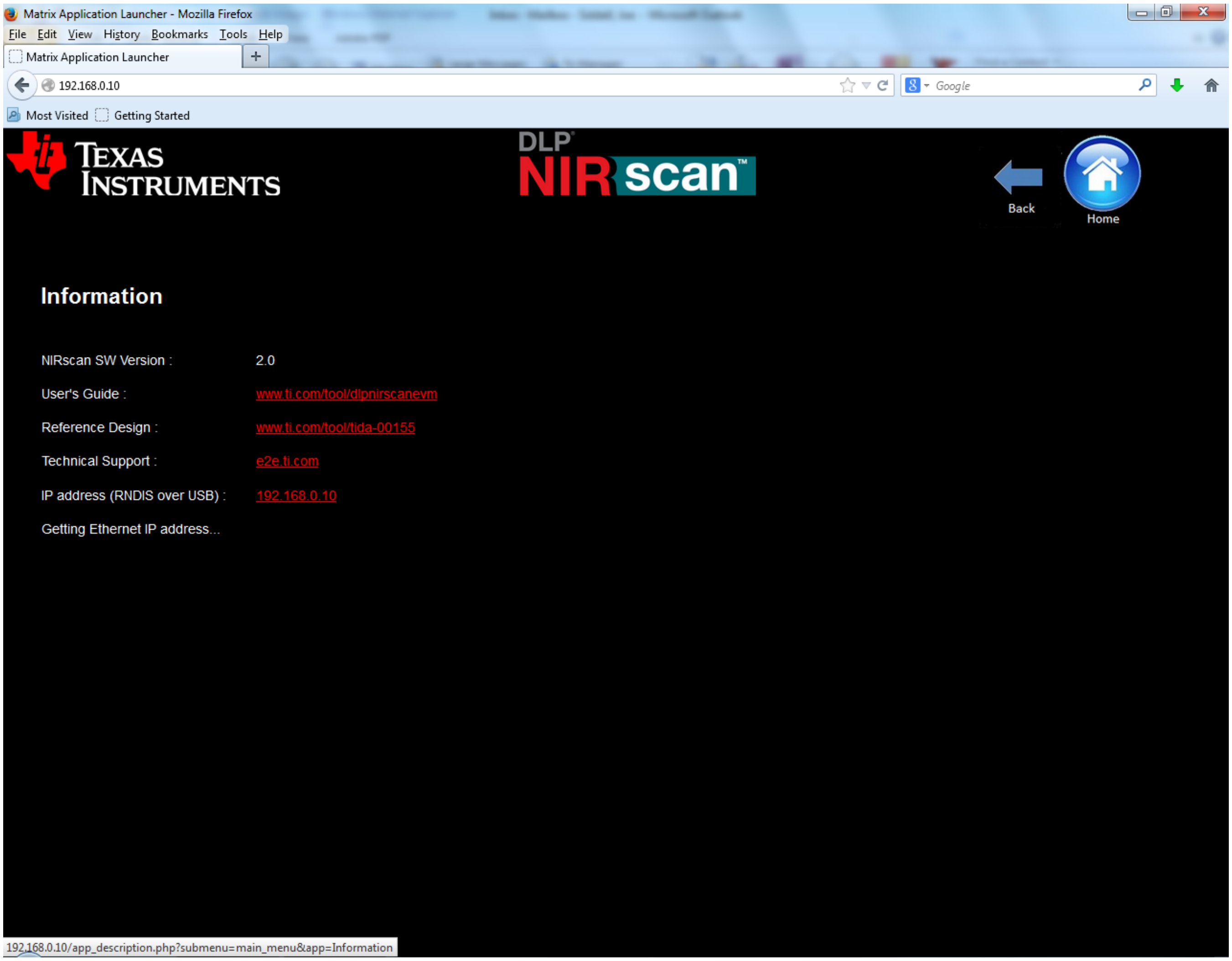
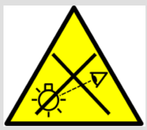


Figure 3-11. Information Screen

The version displayed on the screen is the software version for the Sitara processor. The screen also included hyperlinks to documents relevant to the DLP NIRscan and its components.

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 NIRscan 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 NIRscan EVM does not include a power supply. The external power supply requirements are:

- Nominal voltage: 12 V DC –5% / +10%
- Minimum current: 3 A
- Maximum current: 5 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.

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.

NIRscan EVM Reprogramming Procedure

C.1 Creating a bootable microSD Card

When a new version for the DLP NIRscan EVM is available, the NIRscan can only be reprogrammed by creating and using a micro-SD flash card. A minimum flash card size of 4GB is required. This card must be created using the new version binary located on ti.com and the following procedure.

1. Download the DLP NIRscan MicroSD Image for Windows for programming the NIRscan. This file can be found on the DLP NIRscan EVM website. After signing into TI and starting Download Select RUN (rather than SAVE). The file is approximately 1GB in size. Place this file in a directory which will be easy to locate. Default is C:\Texas Instruments-DLP\NIRscan_2.0.0
2. Unzip the downloaded file into the same directory using Winzip, 7-zip, or another Windows compatible zip/unzip utility. The resulting file will be used in the creation of the micro-SD card that will be used to flash the eMMC of the NIRscan electronics.
3. Download and unzip the Win32DiskImager software into a folder on the PC. If you choose, you can use the same folder as the program to be flashed is in. This software creates and installs the flash image on the micro-SD card.
4. Run the Win32DiskImager application. A small window will appear. If you have questions on how to use the program, you can go to the Help link.
5. Place a blank micro-SD card into the PC SD card slot. Within the Win32DiskImager application, select the drive letter that corresponds to the PC's SD card reader. by clicking on the Device box with a letter in it. MAKE SURE YOU SELECT THE CORRECT DRIVE LETTER.
6. Select the file from the directory that you unzipped the new image to by clicking on the folder icon next to the Device box.
7. Select the write option to start the writing process. Image file is approximately 3GB in size.
8. When finished, remove the microSD card from the reader. The card is now ready to reprogram the DLP NIRscan EVM.

C.2 Reprogramming the DLP NIRscan EVM Application Software

For steps on programming the DLPC350, please see section C.3 below.

1. Prepare the NIRscan by UNPLUGGING ALL CABLES from the unit to be programmed, including the power cable.
2. Insert newly created microSD card into the microSD card slot on the NIRscan Spectral board with contacts facing away from the board as shown in Figure C-1.

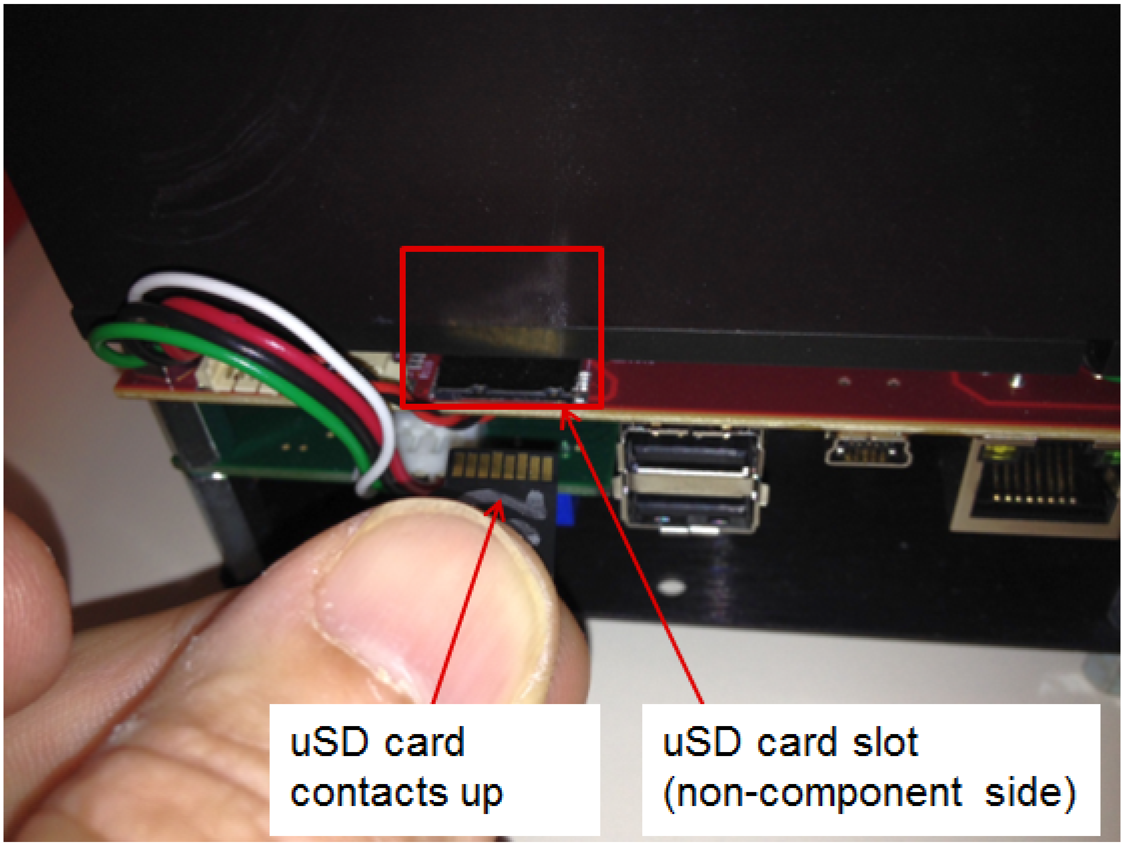


Figure C-1. MicroSD Card Slot

3. Press and hold down switch S2 (shown in Figure C-2) while plugging in the power cable. Do not use any metal tools or objects as these could short potentially damage the electronics if misplaced.

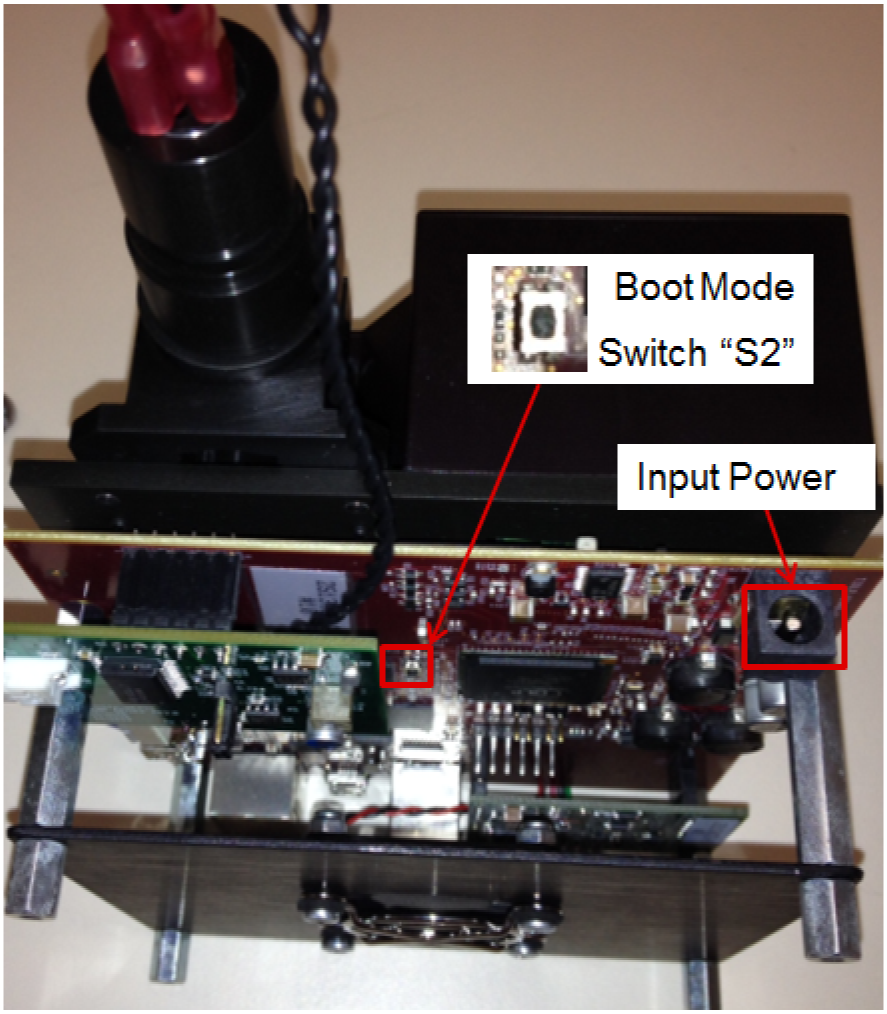


Figure C-2. Boot Switch Location

4. Continue to hold down S2 until any on-board LED lights up (about 1 second) - then release S2.
5. One or both of two blue LEDs (D1 and D2) as shown in Figure C-3, will flash on and off erratically - this indicates the eMMC is being programmed.

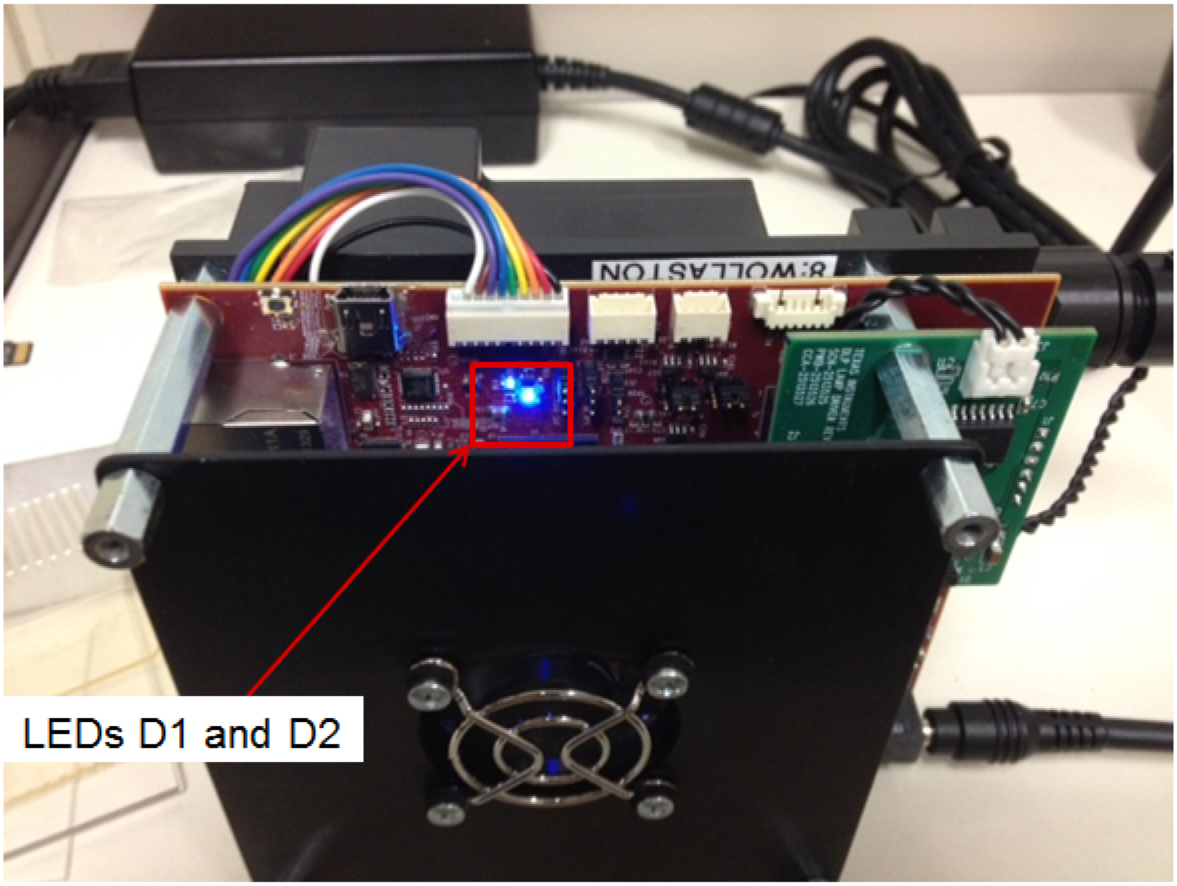


Figure C-3. LED Location

6. Reprogramming should take less than 10 minutes - when D1 and D2 are on steady for at least 20 seconds, the eMMC is flashed.
7. Remove the power from the board by removing the power cable.
8. Remove the microSD card from the board.
9. Reapply the power to the board by plugging in the cable.
10. The NIRscan will boot from the new software. For the first operation after reprogramming, the NIRscan will take slightly longer to boot. Once LED D1 is lit, the NIRscan is ready to communicate. Plug in the USB cable, enter ***http://192.168.0.10*** into your browser URL window, hit enter, and the NIRscan menu should appear.

C.3 Upgrading the DLPC350 Firmware

This section describes how to reprogram the DLP NIRscan EVM with its application software. It should be noted that the NIRscan firmware version and the DLPC350 version have dependencies. Therefore, when upgrading the DLP NIRscan EVM software, it is extremely likely the DLPC350 will also need to be upgraded. See the list below for compatible versions:

- NIRscan version 1.0.0 can only be used with DLPC350 firmware version 1.1
- NIRscan version 2.0.0 can only be used with DLPC350 firmware version 2.0

The steps to reprogram the DLPC350 are:

1. Download the latest DLPC350 firmware version select save rather than open to a directory of your choice and remember the file location. For example, if reprogramming the NIRscan with Application software version 2.0.0, then the DLPR350PROM version selected should be 2.0
2. Download the LightCrafter4500 PC-based GUI. To install the QT GUI, just expand the LightCrafter4500_GUI.zip file into a directory and double-click on the executable file.

3. Turn on the NIRscan and then connect a USB cable from the PC to the DLPC350 USB connector J8.
4. Upon execution of the LightCrafter4500.exe file, the GUI main window will appear and the GUI window should show a green light to the left of the word "Connected" in the upper left corner if the GUI is successful in connecting to the DLPC350.
5. Select the Image / Firmware tab.
6. Select the Firmware Upload subtab.
7. Click the Browse button to select the file to install.
8. Click the Upload button.
9. Wait for the upload process to complete. The flash memory is erased first, then rewritten with the new firmware image selected.
10. Remove power from the NIRscan EVM, close the LightCrafter 4500 GUI, and unplug the USB cable.
11. Plug the USB back into the NIRscan. If the NIRscan application code has already been updated, then the NIRscan is ready to go. If not, then follow the instructions in C.1 and C.2 to reprogram the NIRscan application code.
12. Once both are updated, the NIRscan is ready to function.

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Revision B History

Changes from A Revision (August 2014) to B Revision	Page
• Added DLP Spectrometer Design Considerations as a related document	6
• Changed from Design Guide to Design Considerations and added URL link	32
• Changed to http://192.168.0.10 from http://192.168.1.10	44

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

Revision A History

Changes from Original (April 2014) to A Revision	Page
• Added Browser Recommendations	5
• Home Screen updated for v2.0	20
• Added Slew Scan and Download Files Icons	22
• Update v2.0 Custom Scan image to include instructions.	26
• Added the Slew Scan Mode Instructions	30
• Added the File Download Section	34
• Updated the System Information/Revision screen	34
• Added NIRscan Reprogramming Procedure	41

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

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