

DLP® NIRscan™ Nano EVM User's Guide

User's Guide



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Read This First

About This Guide

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

This guide is an introductory document for the DLP NIRscan Nano EVM that provides an overview of the system and the system software.

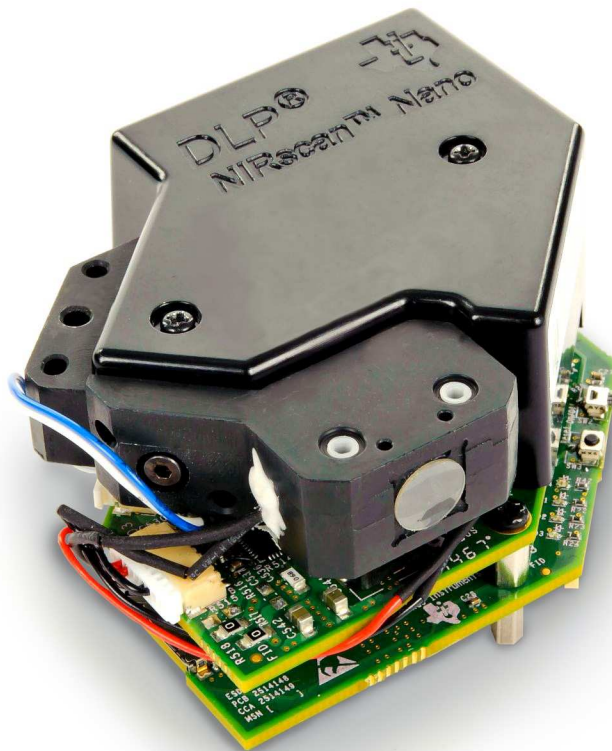


Figure 1. DLP NIRscan Nano Evaluation Module

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Related Documentation from TI

- DLP2010NIR data sheet: *DLP 0.2 WVGA Near-Infrared DMD*, [DLPS059](#)
- DLPC150 data sheet: *DLPC150 DLP Digital Controller for Advanced Light Control*, [DLPS048](#)
- DLPC150 programmer's guide: *DLPC150 Programmer's Guide User's Guide*, [DLPU031](#)
- DLP design guide: *DLP Spectrometer Design Considerations*, [DLPA049](#)
- Tiva™ TM4C1297 data sheet: *Tiva TM4C1297NCZAD Microcontroller Data Sheet* [SPMS435](#)
- TivaWare™ USB library: *TivaWare USB Library User's Guide*, [SPMU297](#)
- TivaWare™ peripheral driver library: *TivaWare Peripheral Driver Library User's Guide*, [SPMU298](#)
- TI-RTOS 2.10: *TI-RTOS 2.10 User's Guide*, [SPRUHD4](#)
- CC2564MODN data sheet: *CC2564MODN Bluetooth® Host Controller Interface Module*, [SWRS160](#)
- ADS1255 data sheet: *Very Low Noise, 24-Bit Analog-to-Digital Converter Data Sheet*, [SBAS288](#)

If You Need Assistance

Search the [DLP and MEMS TI E2E Community Support forums](#).

Search the [TM4C Microcontrollers TI E2E Community Support forums](#).

Search the [Bluetooth® CC256x TI E2E Community Support forums](#).

Search the [SimpleLink™ Bluetooth® CC256x Wiki](#).

DLP NIRscan Nano Overview

1.1 Introduction

The DLP® NIRscan Nano™ EVM is a complete evaluation module to design a high performance, affordable near-infrared portable spectrometer. This flexible tool contains everything a designer needs to start developing a DLP-based spectrometer right out of the box. DLP technology enables handheld spectral analyzers for use in the food, pharmaceutical, oil and gas, medical, security, and other emerging industries to deliver lab performance levels in the field. The EVM contains the DLP2010NIR digital micromirror device, DLPC150 digital controller, and DLPA2005 integrated power management components. This technology brings together a set of components providing an efficient and compelling spectroscopy system solution for:

- Portable process analyzers
- Ultra-mobile spectrometer

The new DLP2010NIR DMD is optimized for operation at wavelengths between 700 and 2500 nm. The DLP NIRscan Nano EVM is one possible implementation of this new DLP technology, operating from 900 to 1700 nm.

1.2 What is the **DLP NIRscan Nano EVM**?

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

- Near-infrared optomechanical spectrometer engine optimized for 900 to 1700 nm wavelength range:
 - Reflective illumination module with two integrated infrared lamps
 - 1.69-mm × 0.25-mm input slit
 - Collimating lenses
 - 885-nm long wavepass filter
 - Reflective diffraction grating
 - Focusing lenses
 - DLP2010NIR DMD (0.2-inch WVGA, 854 × 480 orthogonal pixel, NIR optimized)
 - Collection optics
 - 1-mm single-pixel InGaAs non-cooled detector
- Electronics subsystem with the electronics consisting of four boards:
 - Microcontroller board
 - Tiva TM4C1297 microprocessor for system control operating at 120 MHz
 - 32MB SDRAM for pattern storage
 - Power management with Lithium-polymer or Lithium-ion battery charging circuits using bq24250
 - CC2564MODN Bluetooth Low Energy module for Bluetooth 4.0 connectivity
 - USB micro connector for USB connectivity
 - microSD card slot for external data storage
 - HDC1000 humidity and temperature sensor
 - DLP controller board
 - DLPC150 DLP controller
 - DLPA2005 integrated power management circuit for DMD and DLP controller supplies

- Constant current lamp driver based on OPA567 and monitored by INA213
- Detector board
 - Low-noise differential amplifier circuit
 - ADS1255 30 kSPS analog-to-digital converter (ADC) with SPI
 - TMP006 thermopile sensor for detector and ambient temperature measurement
 - 1-mm non-cooled Hamamatsu G12180-010A InGaAs photodiode
- DMD board
 - DLP2010NIR near-infrared digital micromirror device

Figure 1-1 shows the NIRscan Nano hardware block diagram.

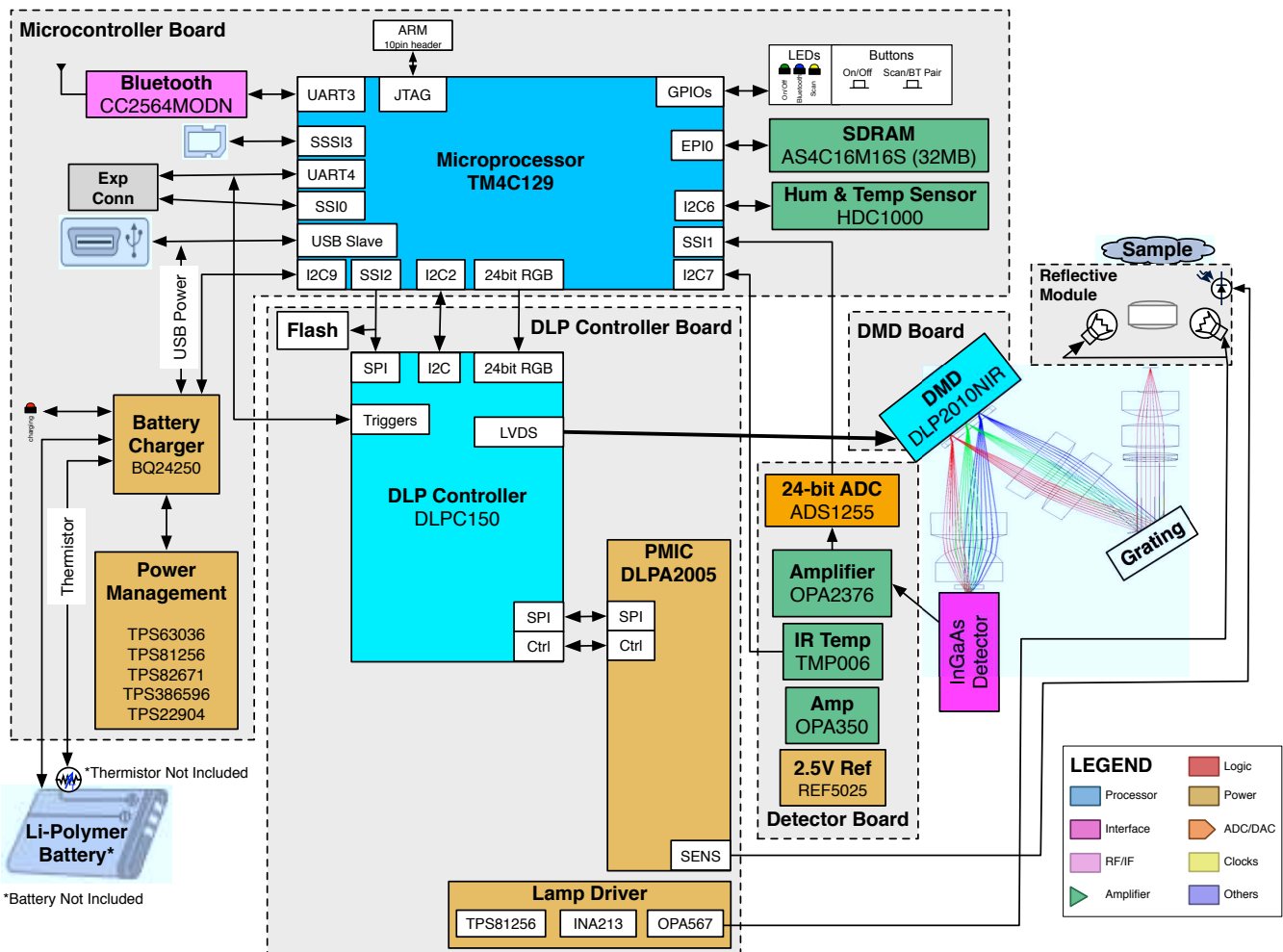


Figure 1-1. DLP NIRscan Nano Block Diagram

1.2.1 Optical Engine

The DLP NIRscan Nano EVM spectrometer optical engine is mounted on top of the electronics subsystem. The configuration is a post-dispersive architecture with a removable reflectance sample module. The reflectance module includes two lens-end broadband tungsten filament lamps. In this specific implementation, depicted in Figure 1-2, a sample is placed against the sapphire front window of the reflectance head. During a scan, the sample absorbs a specific amount of NIR light and diffusely reflects the non-absorbed light into the system. The amount of light absorbed at each wavelength is dependent on the molecular makeup of the material, and is specific to that material, a *chemical fingerprint*. The light diffusely reflected from the sample is gathered by the collection lens and focused into the optical engine

through the input slit. The slit size is chosen to balance wavelength resolution with SNR of the spectrometer. This spectrometer uses a 25- μm wide by 1.69-mm tall slit. The light that passes through the slit is collimated by the first set of lenses, passes through an 885-nm long wavepass filter, and then strikes a reflective grating. This grating, in combination with the focusing lens, disperses the light into its constituent wavelengths. The focusing lenses form an image of the slit at the DLP2010NIR DMD. Different wavelengths of this slit image are spread horizontally across the DLP2010NIR DMD. The optical system images 900-nm wavelengths to one end of the DMD and 1700-nm to the other end, with all other wavelengths dispersed in between. When specific DMD columns are selected as *on*, or tilted to the $+17^\circ$ position, the energy reflected by the selected columns is directed through the collection optics to the single pixel InGaAs detector. All other DMD columns selected as *off*, or tilted to the -17° position, diverts the unselected wavelengths away from the detector optical path so as not to interfere with the selected wavelength measurement.

The DLP NIRscan Nano reflectance module operates by illuminating the sample under test at an angle so that specular reflections are not collected, while gathering and focusing diffuse reflections to the slit. The illuminating lamps are designated as *lens-end* lamps because the front end of the glass bulb is formed into a lens that directs more light from the filament to the sample test region. The collection lens gathers collimated light from a 2.5-mm diameter region at the sample window. The size of the collection region was matched to the nominal illumination spot size created by the lens-end lamps. This requires that the sample be placed directly against the sapphire window, where the two angled light source paths intersect the collection vision cone of the lens. If the sample is shifted farther away from the window, the sample may not receive enough illumination for the system to perform an accurate scan.

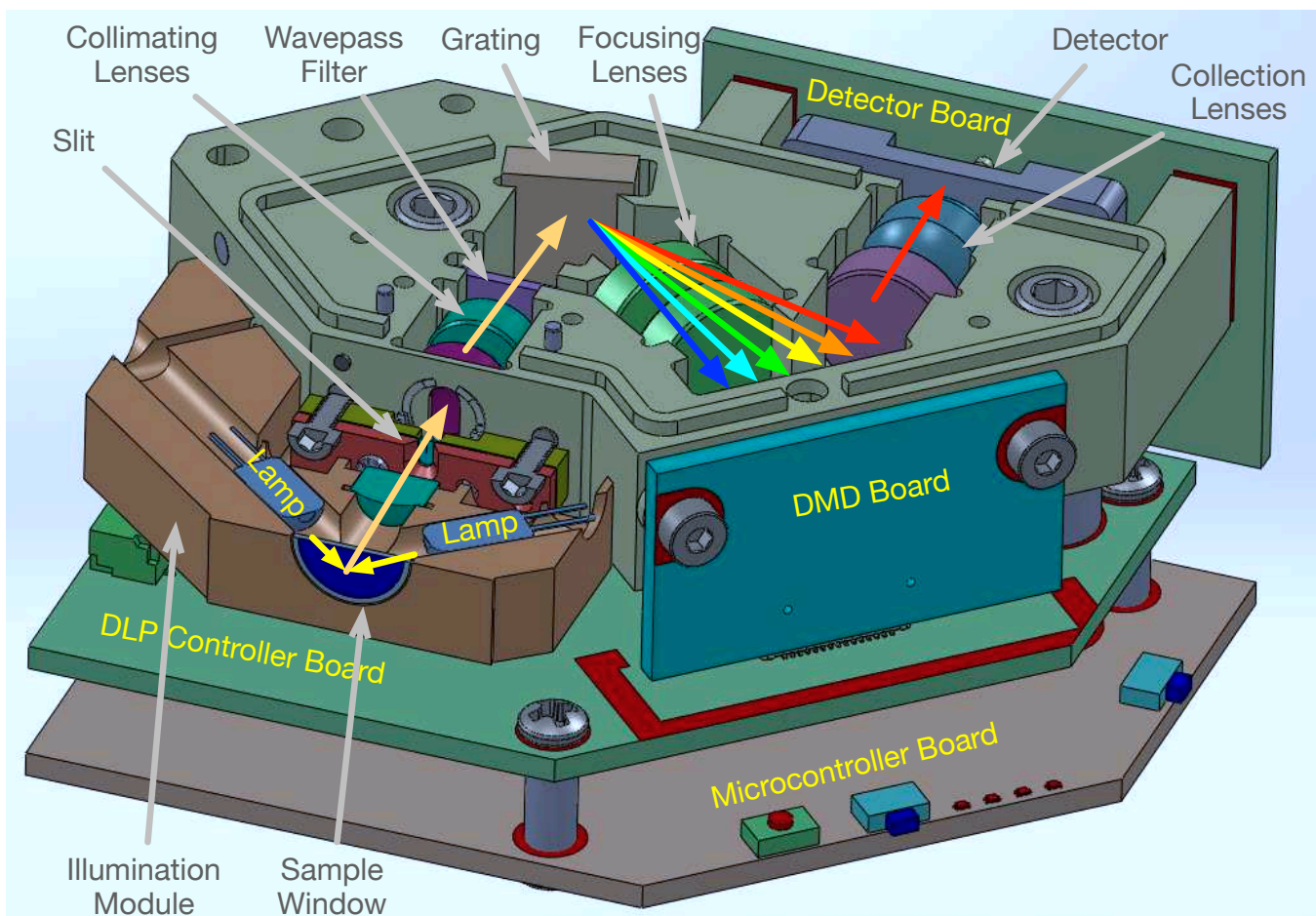


Figure 1-2. DLP NIRscan Nano Optical Engine

The optical engine footprint drives the size of the DLP NIRscan Nano EVM. The NIRscan Nano EVM measures approximately 62-mm long, 58-mm wide, and 36-mm tall as shown in [Figure 1-3](#).

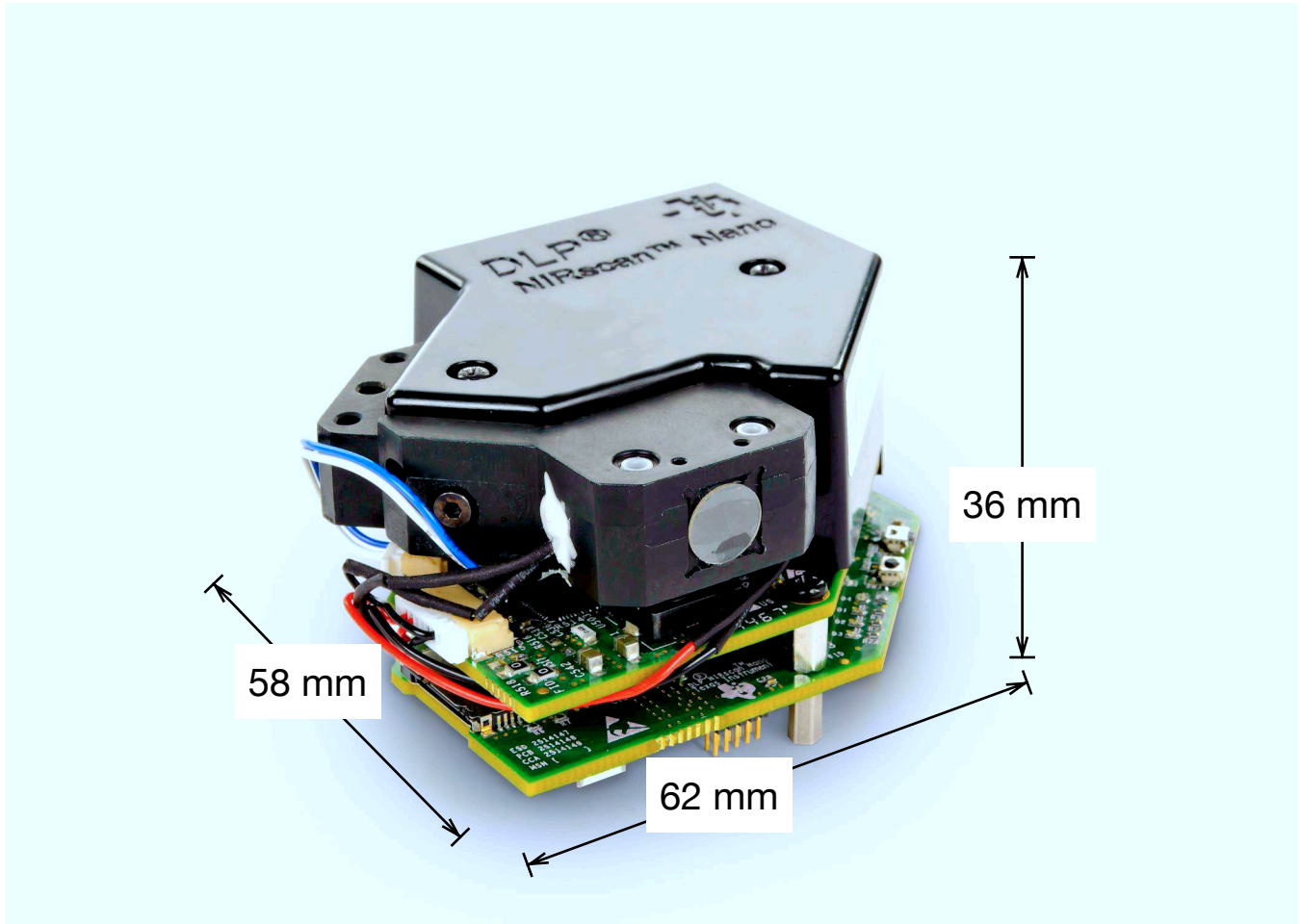


Figure 1-3. DLP NIRscan Nano Dimensions

Table 1-1 lists the specifications of the DLP NIRscan Nano EVM.

Table 1-1. DLP NIRscan Nano EVM Specifications

PARAMETER	MIN	TYP	MAX	UNIT
Supported wavelengths	900		1700	nm
Optical resolution		10	12	nm
Lamp power		1.4		W

1.2.2 DLP NIRscan Nano Electronics

The DLP NIRscan Nano EVM contains the following four boards:

- **Microcontroller board:** The Microcontroller board is the largest board in the DLP NIRscan Nano EVM. This board includes the following:
 - Tiva TM4C1297 microcontroller: The Tiva processor controls the whole system. The Tiva runs the TI realtime operating system (RTOS), the Bluetopia stack, and the spectroscopy software. When it receives a scan command through USB, Bluetooth, or through pressing the scan button, the Tiva streams through its LCD interface a set of unique wavelength specific patterns to the DLPC150 for display on the DMD while synchronizing the sampling of the spectrometer's ADC. An external 32MB SDRAM allows for additional code storage and stores the pattern buffer streamed to the DLPC150.
 - External interfaces: The Microcontroller board provides two main interfaces to the outside world: USB and Bluetooth Low Energy. To leverage the DLP NIRscan EVM platform for new product development using the Tiva processor, the microcontroller board also contains a Tiva debug JTAG port, which can be used with Code Composer Studio™ emulation software and XDS100, XDS200, or XDS560 emulators. The Microcontroller board also includes an expansion connector with SPI, UART, and GPIO capability for connection to external systems.
 - Battery charging circuits: An optional 3.7-V Lithium-Ion or Lithium-Polymer can be added to power the system. The on-board power management circuits of the bq24250 device take power from USB and simultaneously charge the battery if its voltage is below 4.2 V at up to 1-A charge current. The bq24250 also monitors an optional thermistor for battery temperature monitoring during charge.
 - microSD card connector: The microSD card connector allows additional storage for scan data when the system is not connected to a PC nor iOS device.
 - HDC1000 humidity and temperature sensor: Measures the humidity and temperature of the system. These values are captured with each scan.
- **DLP controller board:** The DLPC150 controller board is the second largest board in the DLP NIRscan Nano EVM. This board includes the following:
 - DLPC150 controller: The DLPC150 receives the pattern data from the Tiva TM4C1297 processor over a 24-bit RGB bus. The DLPC150 decodes the pattern information and converts the information into the correct format for the DLP2010NIR DMD. The DLPC150 controls and synchronizes all the DMD signals, thereby directing each individual mirror to its desired state.
 - DLPA2005 PMIC: The DLPA2005 is a power management IC that controls all the supplies to the DLP2010NIR DMD and the DMD interface portion of the DLPC150 supplies.
 - Lamp driver circuit: To provide constant current to the near-infrared lamps, a OPA567 based power amplifier circuit regulates the current to the lamps to 280 mA at 5 V based on the voltage across a sense resistor monitored by the INA213 current shunt monitor.
- **Detector board:** The detector board includes the following:
 - Transimpedance low-noise amplifier: Amplifies the signal from the InGaAs detector to the ADC.
 - ADS1255 ADC: Converts the amplified signal of the InGaAs detector into a 24-bit value for Tiva processing.
 - TMP006 thermopile sensor: Measures the InGaAs detector temperature and ambient temperature of the system. These values are captured with each scan.
 - 1-mm non-cooled Hamamatsu G12180-010A InGaAs photodiode
- **DMD board:** The DMD board includes the DLP near-infrared digital micromirror.

The DLP NIRscan Nano electronics contain many devices manufactured by Texas Instruments. [Table 1-2](#) lists the main parts and their functions.

Table 1-2. DLP NIRscan Nano Electronics

Device	Electronic Subsystem	Electronics Type	Description
TM4C1297	Microcontroller board	Microprocessor	Cortex-M4 microprocessor operating at 120 MHz with integrated 1MB flash, 256K SRAM, and USB 2.0 interface.
bq24250		Battery charger	Single cell Lithium-Ion or Lithium-Polymer battery charger with up to 1-A charge current from USB. Battery is charged in four phases: trickle charge, precharge, constant current, and constant voltage. In all charge phases, an optional battery pack thermistor monitors the battery temperature for safe charging.
CC2465MODN		Bluetooth Low Energy host controller interface module	Single chip Bluetooth 4.1 Low Energy subsystem module with on-board antenna.
HDC1000		Sensor	Low power, high accuracy temperature and humidity sensor with 14-bit resolution.
TPS63036		Power management	High-efficiency buck-boost converter in wafer chip scale package supplies 3.3 V.
TPS81256			High-efficiency step-up converter in microSIP package supplies 5.0 V for analog circuits.
TPS82671			High-efficiency step-down converter in microSIP package supplies 1.8 V.
TPS386596			Quad reset supervisor
TPS22904			Load switch supplies 1.8 V for Bluetooth circuits.
DLPC150		DLP controller board	DLP
DLPA2005	DLP power management		DLP power management integrated circuit that powers the DLP 1.8-V, 10-V, 18-V, and -14-V supplies.
TPS81256	Power management		High efficiency step-up converter in microSIP package that supplies the 5 V for the lamp driver
OPA567	Power amplifier		2-A power amplifier that supplies 280-mA lamp current.
INA213	Analog monitor		Voltage output, current-shunt monitor that monitors lamp current.
ADS1255	Detector board	Analog	Very-low-noise 24-bit analog-to-digital converter. Converts the analog output of the InGaAs detector into a 24-bit digital value.
REF5025		Power management	Low-noise, very-low-drift, precision voltage reference that provides the 2.5-V reference for the transimpedance amplifier.
OPA2376		Precision amplifier	Low-noise precision operational amplifier. Used as a transimpedance amplifier for the InGaAs detector.
OPA350			High-speed operation amplifier that buffers the 2.5-V reference voltage of the transimpedance amplifier.
TMP006		Sensor	Infrared thermopile sensor that measures ambient and detector temperature
DLP2010NIR	DMD board	DLP	DLP near-infrared digital micromirror

1.2.3 Connections

Table 1-3 lists the DLP NIRscan Nano connectors with its locations shown in Figure 1-4 and Figure 1-5.

Table 1-3. DLP NIRscan Nano Connectors

BOARD	SCHEMATIC LABEL	DESCRIPTION
Microcontroller board	J1	Micro-USB connector: Provides power and PC connectivity with HID commands
	J2	Detector board interface: Provides Tiva's SSI1 connection to ADS1255 and Tiva's I2C7 to TMP006
	J3	Expansion connector: Provides Tiva's UART4 or SSI0 interface to external device. UART4 is used as Tiva's console output for debugging information
	J4	JTAG connector: ARM Cortex 10-pin emulation (XDS100, XDS200, or XDS560) connection
	J6	Lithium-Ion or Lithium-Polymer battery connection
	J7	Battery thermistor connection
DLP controller board	J500	Trigger connector. This connector is covered by the top cover. Access to this connector requires to removal of the Microcontroller and DLP controller boards from the optical engine
	J501	Lamp photodetector connector
	J503	Lamp power connector

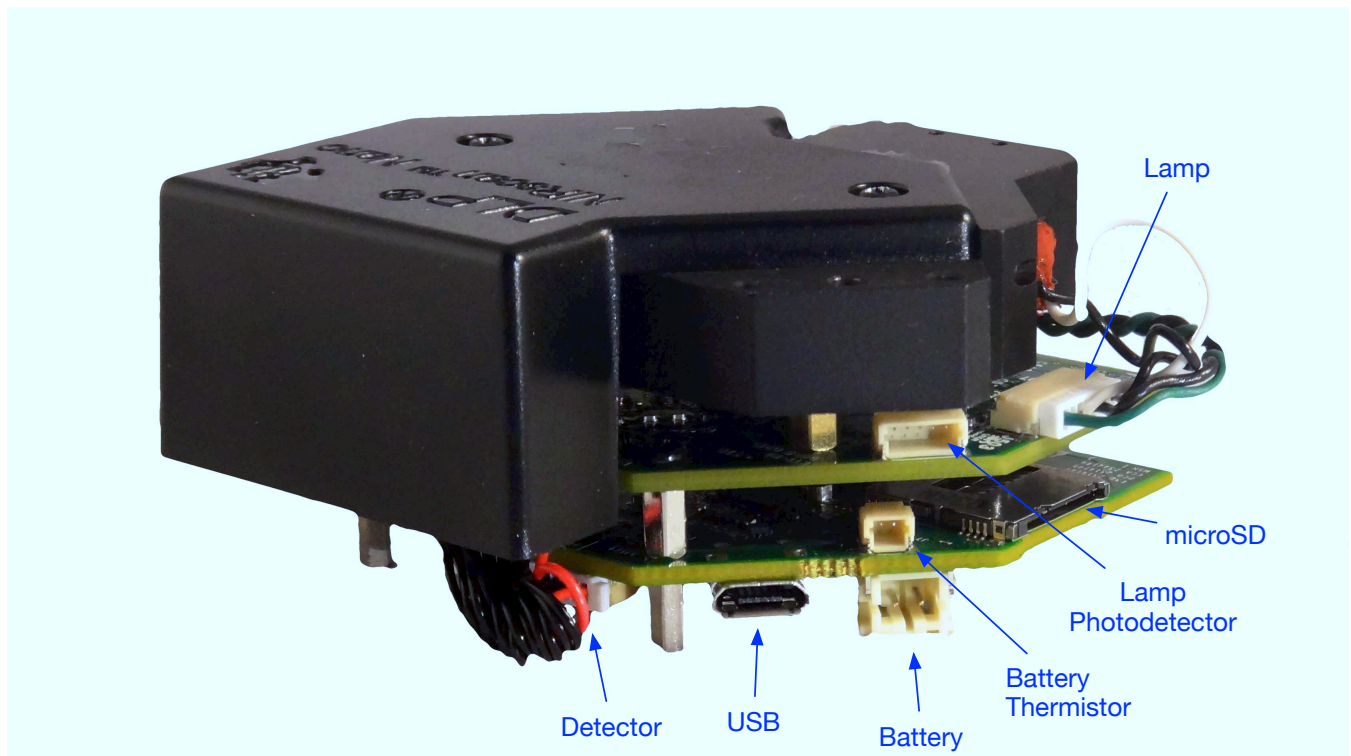


Figure 1-4. DLP NIRscan Connectors (Rear View)

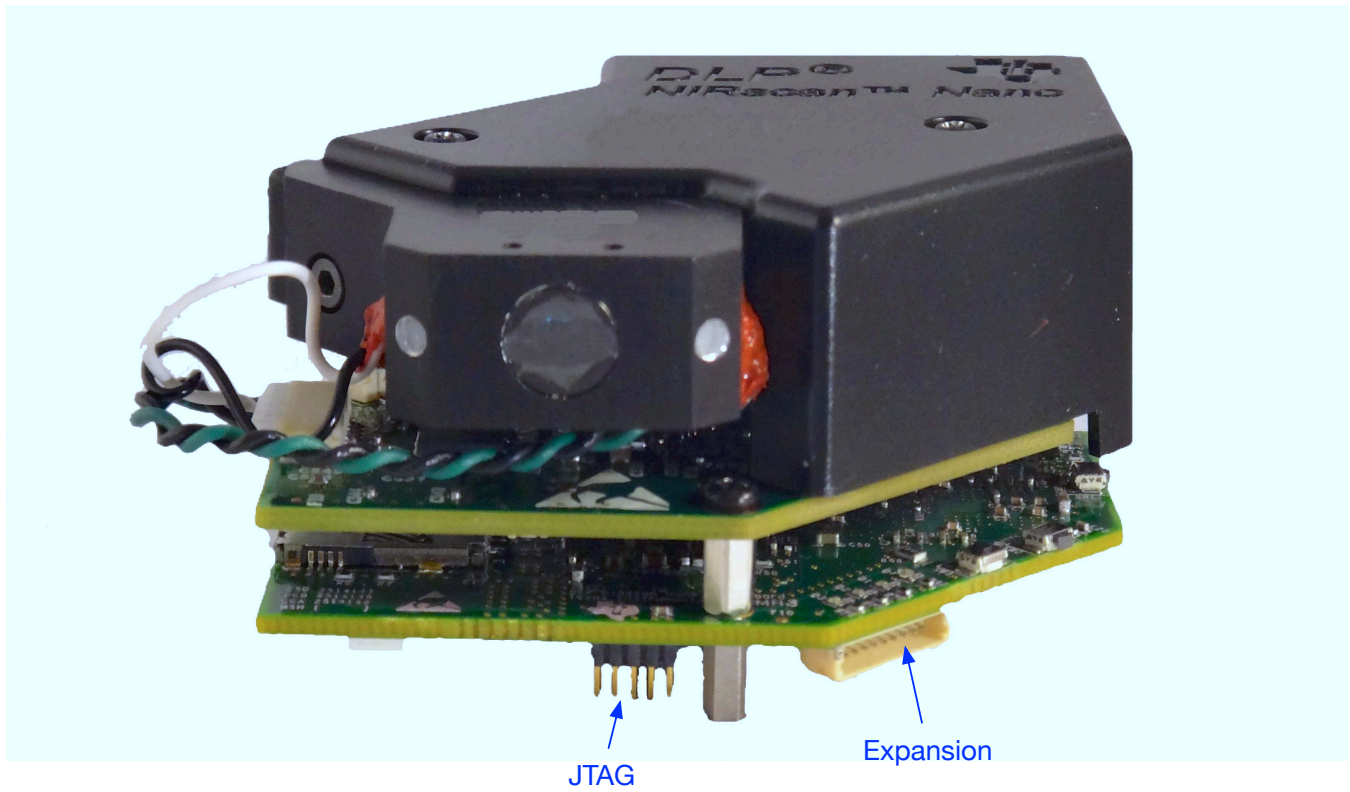


Figure 1-5. DLP NIRscan Connectors (Front View)

1.2.3.1 Buttons

The DLP NIRscan Nano EVM includes three buttons:

- Wake button:
 - When the system is in standby, pressing the Wake button will wake the system from hibernation mode.
 - Upon wake up, the green LED will pulse on and off.
- Scan/Bluetooth button:
 - When pressed and released, the system performs a scan. During a scan, the yellow LED is illuminated and the lamps will turn on for the duration of the scan.
 - When pressed, held for more than 3 seconds, and then released, the Bluetooth subsystem powers up and advertises a connection. While a Bluetooth Low Energy connection is advertised, the blue LED will turn on. When a Bluetooth Low Energy connection is active, the blue LED will pulse off and on. The pulsing may coincide with the green LED or may pulse opposite to the green LED pulses.
- Reset button:
 - Pressing the Reset button will initiate a hardware reset of the NIRscan Nano system.

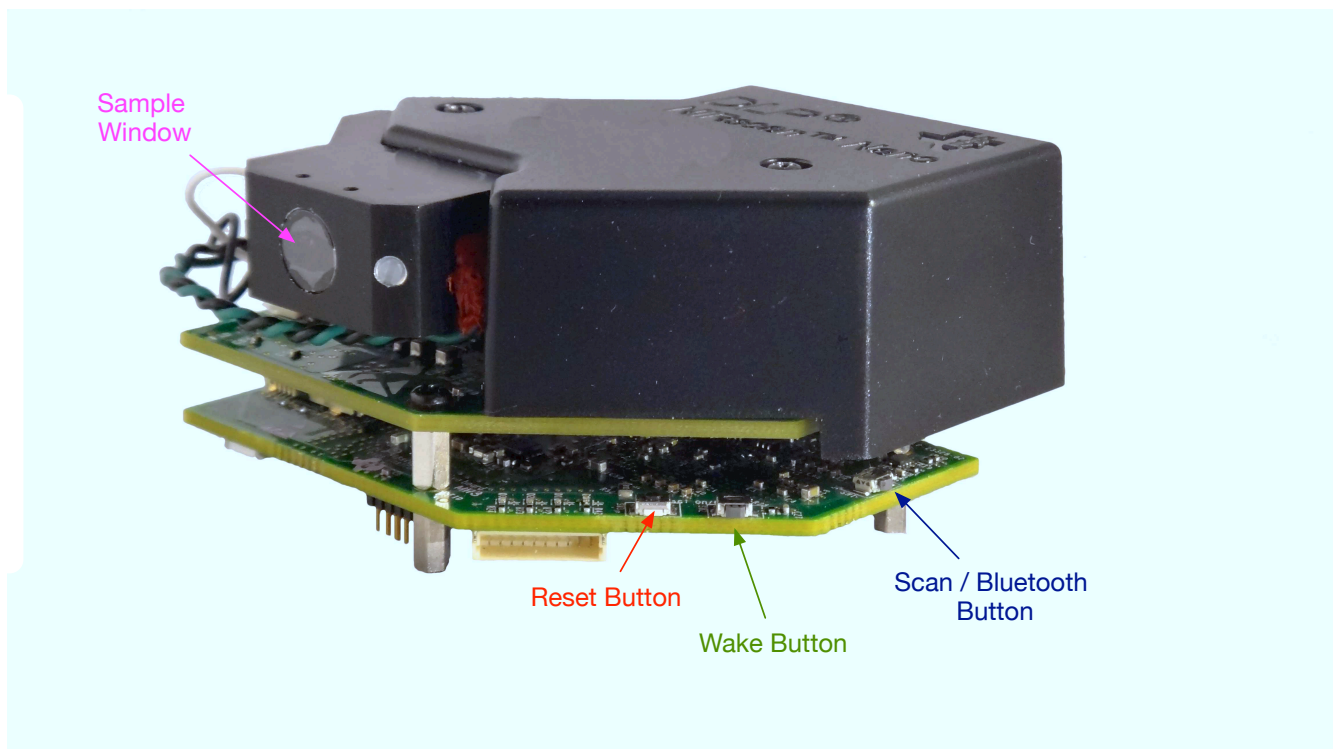


Figure 1-6. DLP NIRscan Nano Button Locations

1.2.3.1.1 LEDs

The DLP NIRscan Nano EVM includes four LEDs to indicate activity as shown in [Table 1-4](#).

Table 1-4. DLP NIRscan Nano LED Indicators

LED	CONDITION	DESCRIPTION
Green	Pulse on and off, once a second	Indicates system is powered and active
Blue	ON	Bluetooth circuits are active and advertizing
	Pulse on and off, once a second	Bluetooth Low Energy connection has been established
Yellow	ON	Scan is being performed
Red	ON	System is charging a battery

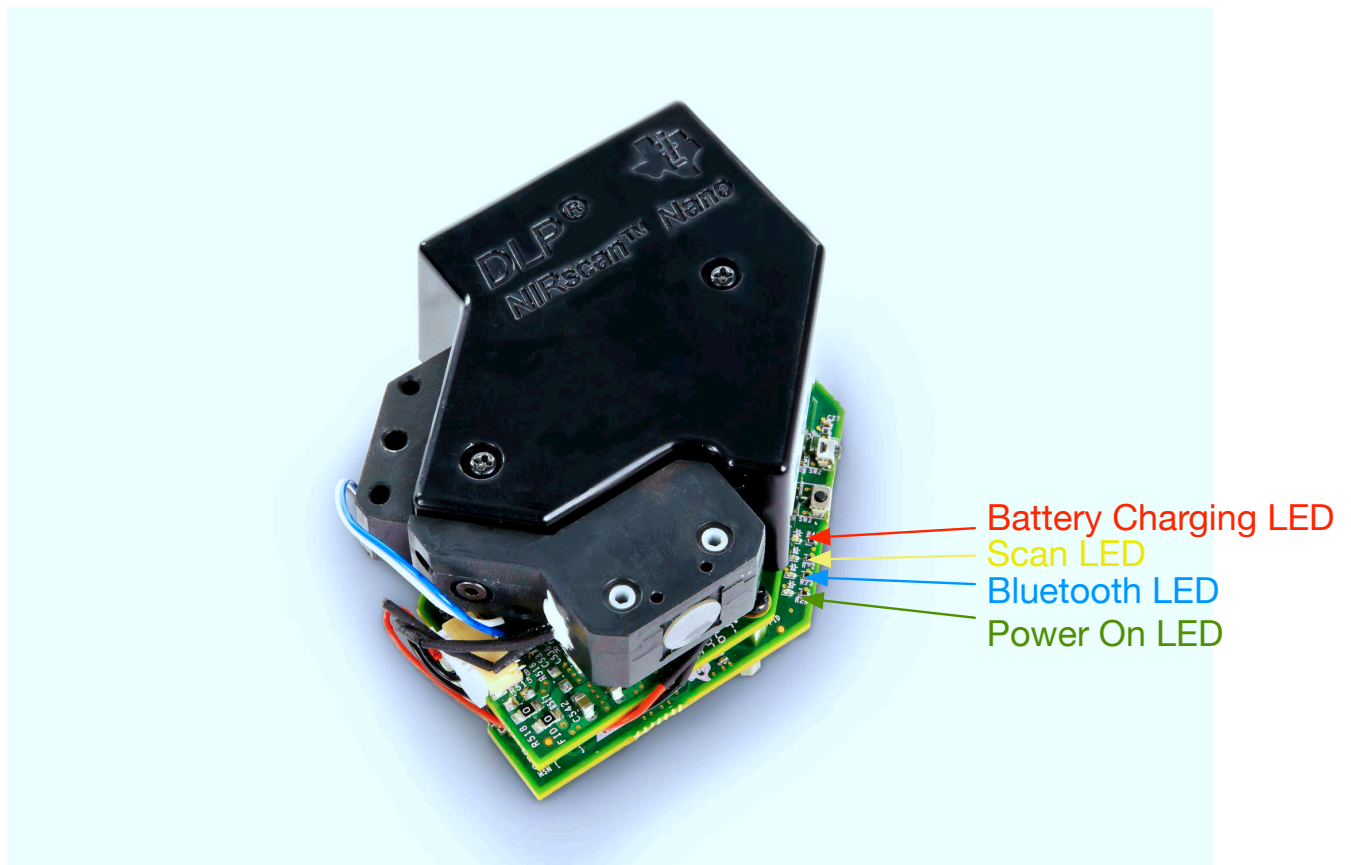


Figure 1-7. DLP NIRscan Nano LED Locations

Getting Started

2.1 Operating Modes

The DLP NIRscan Nano supports the following modes of operation:

- USB connection: A Windows® application with a graphical user interface (GUI), running on a PC with the Windows 7 or 8 operating system, controls the system. Control includes scan initiation, parameter settings, and data download. The PC GUI displays the intensity or absorbance of the scan. The PC powers the NIRscan Nano through the USB cable.
- Bluetooth connection: An iOS app (available from KS Technologies through the Apple® App StoreSM) running on an iPhone® or iPad® with iOS 7.1 or later operating system controls the system. Control includes scan initiation, parameter settings, and downloading data. The iOS app displays the intensity or absorbance of the scan. A USB cable or optional battery powers the NIRscan Nano.
- Standalone: The NIRscan Nano can be preconfigured through the PC GUI or Bluetooth iOS app. Scans are invoked through the Scan button and data is stored on the on-board SDRAM or microSD card. The stored scan data can be later downloaded to a host PC through USB or Bluetooth connection.

2.1.1 USB Connection

When a USB cable is inserted into the DLP NIRscan NanoJ1 micro-USB connector (see [Figure 1-4](#)), the system powers up from the PC's USB VBUS 5-V supply, and the power-on LED pulses to indicate the system is operational and ready for a command. The PC GUI will show as connected after the DLP NIRscan Nano enumerates through USB.

2.1.1.1 NIRscan Nano GUI

The DLP NIRscan Nano software includes a QT-based PC GUI called NIRscanNanoGUI.exe. This GUI requires the following dynamic link libraries (DLLs) to reside in the same directory as the executable file:

- hidapi.dll — USB human interface device (HID) class communication driver
- icudt53.dll — Qt Creator v5.3 Unicode library
- icuin53.dll — Qt Creator v5.3 Unicode library
- icuuc53.dll — Qt Creator v5.3 Unicode library
- libgcc_sdw2-1.dll — GCC library
- libstdc++6.dll — Standard C++ library
- libwinpthread-1.dll — Pthreads for Windows library
- Qt5Core.dll — Qt Core class library
- Qt5Gui.dll — Qt Graphical User Interface class library
- Qt5Svg.dll — Qt Scalable vector graphics class library
- Qt5Widgets.dll — Qt Widgets class library
- platforms/qwindows.dll — Platform plugin for Windows applications
- lmdfu.dll — Tiva USB device firmware upgrade
- lmusb.dll — Tiva USB driver

The Qt windeployqt executable will list all the DLLs necessary by a Qt application.

2.1.2 **Bluetooth Connection**

To connect to the DLP NIRscan Nano, the Bluetooth circuits must first be powered. The following steps activate the Bluetooth circuits:

1. Press the Scan/Bluetooth button and hold it for more than 3 seconds to power the Bluetooth circuits.
2. After the Bluetooth circuits are powered and active, the blue LED turns on and the DLP NIRscan Nano advertises its presence through Bluetooth.
3. Run the iOS App and click the Scan button at the top-right of the screen. This will establish a connection with the DLP NIRscan Nano. The Bluetooth icon on the top-right of the screen will flash.
4. After the DLP NIRscan Nano establishes connection, the blue LED will pulse to indicate that the connection was successful.

Operating the DLP NIRscan Nano EVM

3.1 NIRscan Nano GUI

Upon execution of the NIRscanNanoGUI.exe, the software checks for the DLP NIRscan Nano EVM enumerating through USB and displays the information screen shown in [Figure 3-1](#). The GUI is divided into two sections:

- The top section displays the connected state of the DLP NIRscan Nano EVM on the top-right side. It also has four buttons:
 - Information: Changes the bottom portion of the GUI to display version information, and links to online resources.
 - Scan: Changes the bottom portion of the GUI to display spectrum plots and controls for scan configurations and parameters.
 - Utilities: Changes the bottom portion of the GUI to display sensor information and to synchronize data and time with PC, ADC PGA settings, and firmware upgrades.
 - Connected Status Button: Once a DLP NIRscan Nano enumerates, the icon in the connected status button will change from a gray indicator light with a "Not Connected" message to a green indicator light with a "Connected" message. Pressing this button has no effect. Disconnecting the DLP NIRscan Nano, powering down the device, or resetting the DLP NIRscan Nano will toggle the state of this button.
- The lower section displays information related to the three main operational modes: information, scan, and utilities.

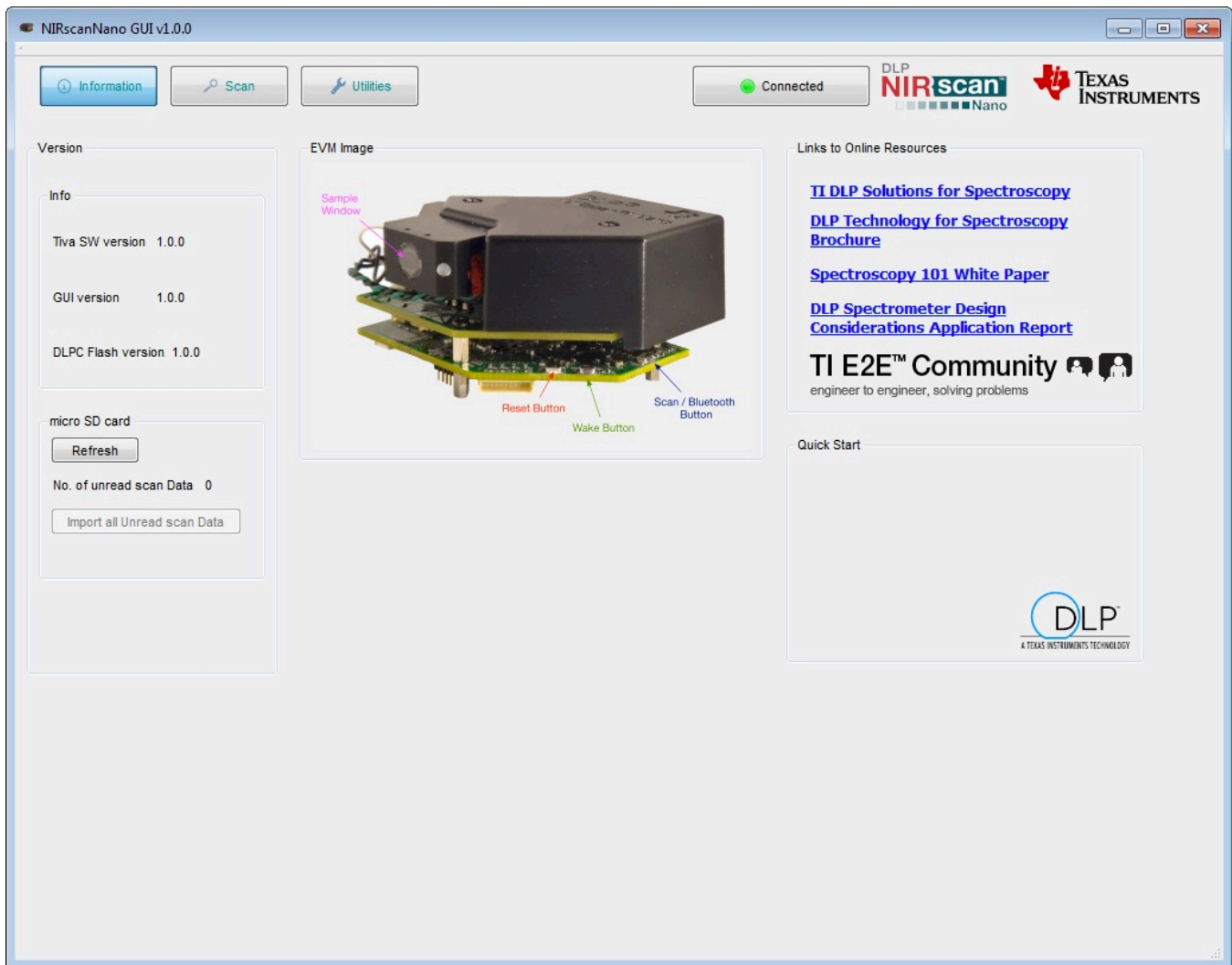


Figure 3-1. DLP NIRscanNano GUI Information Screen

The information screen displays:

- Version information, including the version number of the Tiva and DLPC150 firmware, as well as the GUI software version number.
- EVM image, which displays the locations of the buttons and their functionality.
- Links to online resources, including Texas Instruments DLP brochures, white papers, and application notes on spectroscopy with DLP technology. For support, users can search TI's E2E Community. The TI E2E icon includes a link to direct users to the Texas Instruments DLP E2E forums.
- Presence of microSD card by clicking the Refresh button. Under this button, the "Import all Unread scan Data" buttons transfer any scan data residing on the microSD card to the PC.

3.1.1 Scanning a Sample

The Scan button at the top of the NIRscan Nano GUI displays spectrum plots and controls scan configurations and parameters, as shown in [Figure 3-2](#).

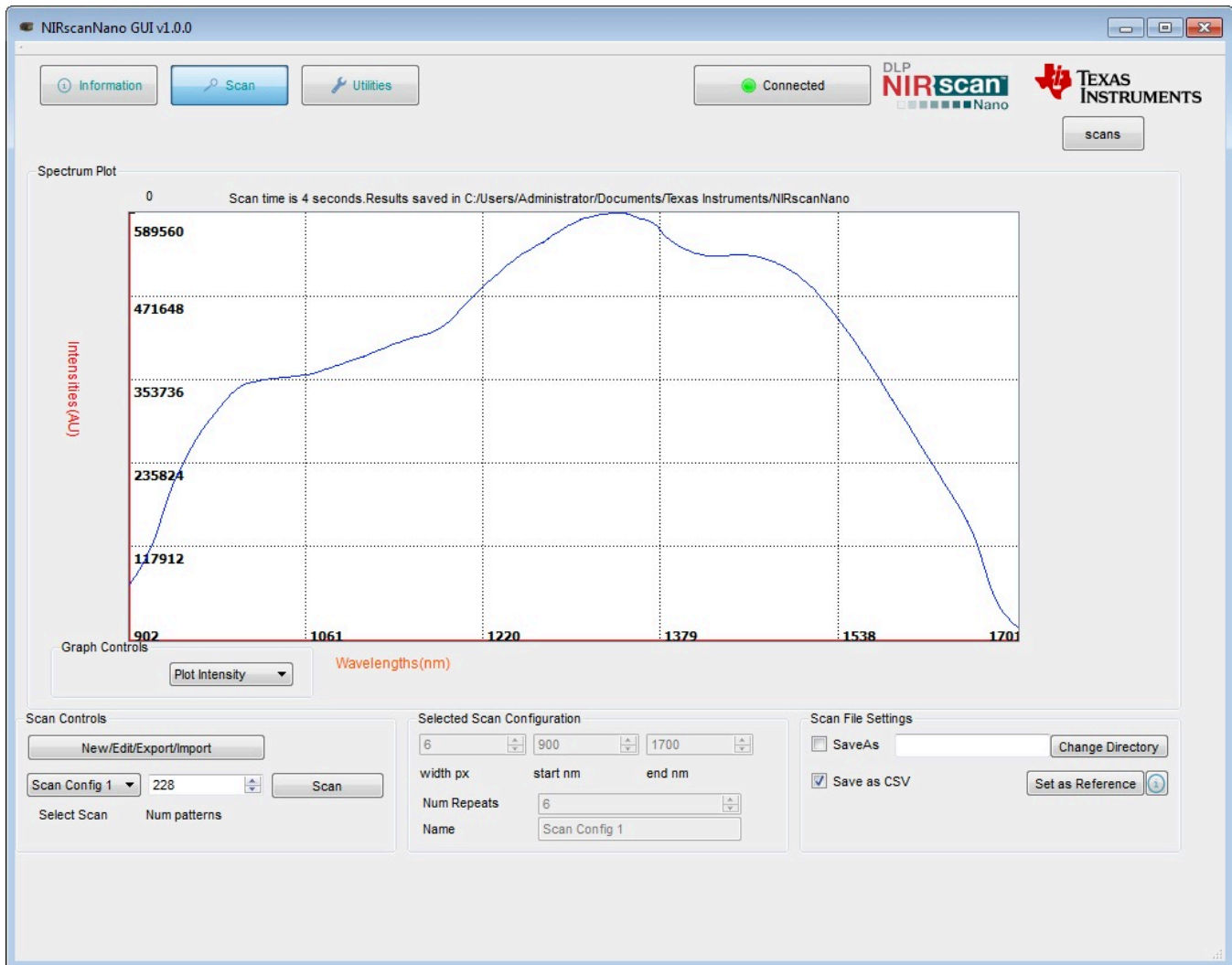


Figure 3-2. DLP NIRscanNano GUI Scan Screen

A scan configuration must be created to scan a sample. (See [Figure 3-3](#) for the Scan Configuration dialog screen.) **A scan configuration specifies the following parameters of a scan:**

- **Wavelength range:** Start and End wavelengths (in nm) or spectral range of interest for the scan. The minimum wavelength is 900 nm and the maximum wavelength is 1700 nm.
- **Width in nm:** This number must be greater than 8 nm and corresponds to the desired smallest wavelength content that you want to resolve in a scan. The DLP NIRscan Nano optical resolution is 10 nm, so values less than 10 nm result in lower signal intensity.
- **Number of patterns:** This number defines how many wavelength points are captured across the defined spectral range. Depending on the previous setting, the GUI computes the maximum number of patterns and indicates them as the "Max Limit."
- **Number of scans to average:** This is the repeated back-to-back scans that are averaged together.

Typical scan configuration parameters for four type of scans that resolve wavelength content in 20-, 15-, 10-, and 8-nm, are shown in [Table 3-1](#).

Table 3-1. Typical Scan Configuration Parameters

SCAN CONFIGURATION PARAMETERS	20-nm CONTENT	15-nm CONTENT	10-nm CONTENT	8-nm CONTENT	
Wavelength range	900 to 1700 nm	900 to 1700 nm	900 to 1700 nm	900 to 1700 nm	900 to 1700 nm
Width in nm	20	15	10	8	8
Number of patterns	80	108	160	225	248
Oversampling	2	2	2	2.25	2.48
Number of scans to average	18	12	8 to 9	6	5

The following steps create a scan configuration:

1. Click the "New/Edit/Export/Import" button in the Scan control box to invoke the Scan Configuration dialog box.
2. The Scan Configuration dialog box shown in [Figure 3-3](#) has three sections:
 - The top-left section displays previous scan configurations saved to the PC.
 - The top-right section displays the scan configurations saved on the DLP NIRscan Nano EVM.
 - The bottom section displays the scan configuration parameters of the selected PC or DLP NIRscan Nano EVM stored scan configuration.
3. Click the New button in the top-left section of the Scan Configuration dialog. Then, type the desired spectral range between 900 and 1700 nm.
4. Select the width in nm that corresponds to the smallest wavelength content that you want to resolve.
5. Enter the desired number of wavelength points captured across the spectral range.
6. Enter the number of scans to average for corresponding back-to-back scans to average.
7. Enter a configuration name and click Save.
8. Close the Scan Configuration dialog by clicking OK.

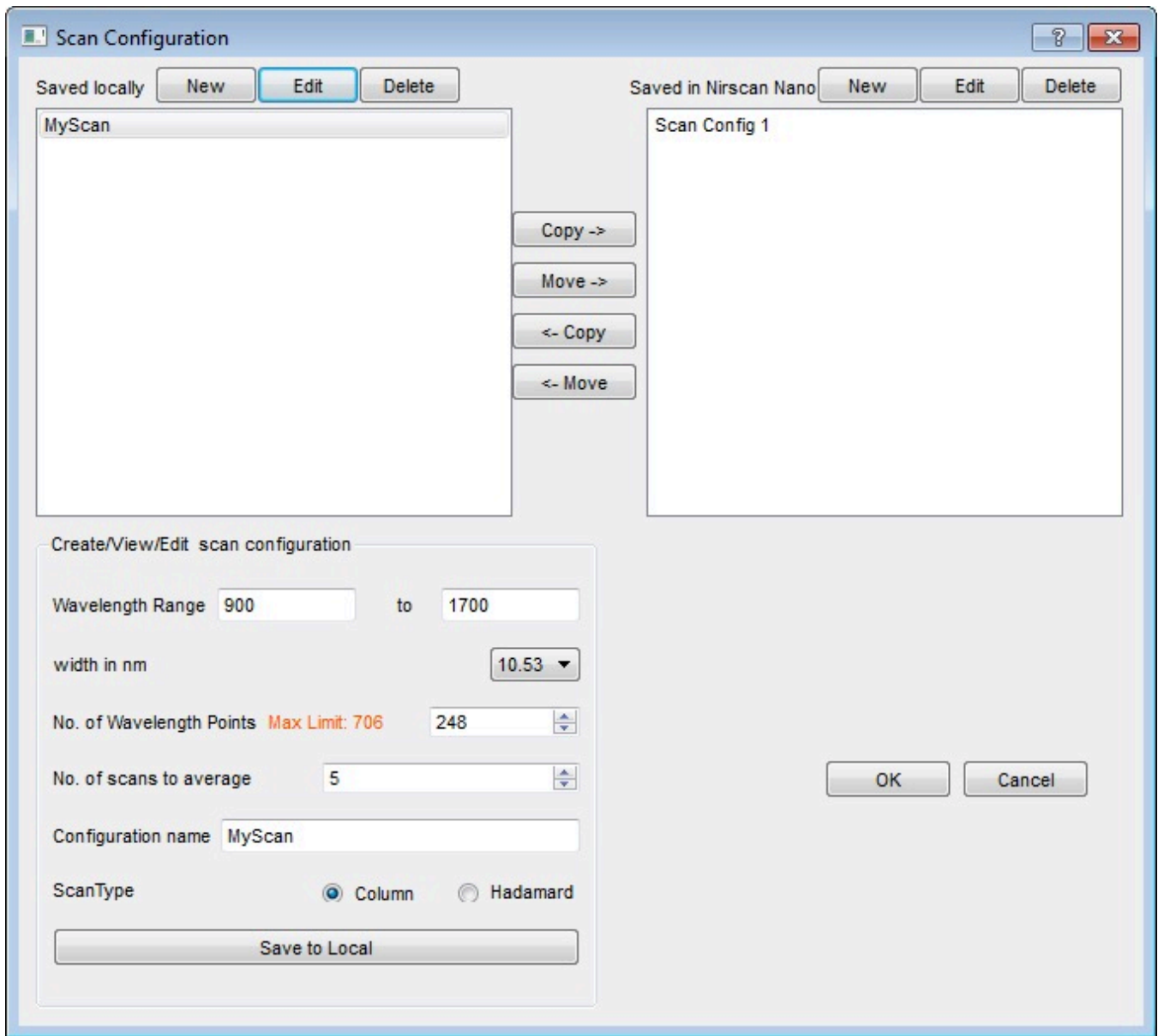


Figure 3-3. DLP NIRscanNano GUI Scan Configuration Dialog

After a scan configuration is defined, it appears under the Select Scan drop-down menu, as shown in Figure 3-4.

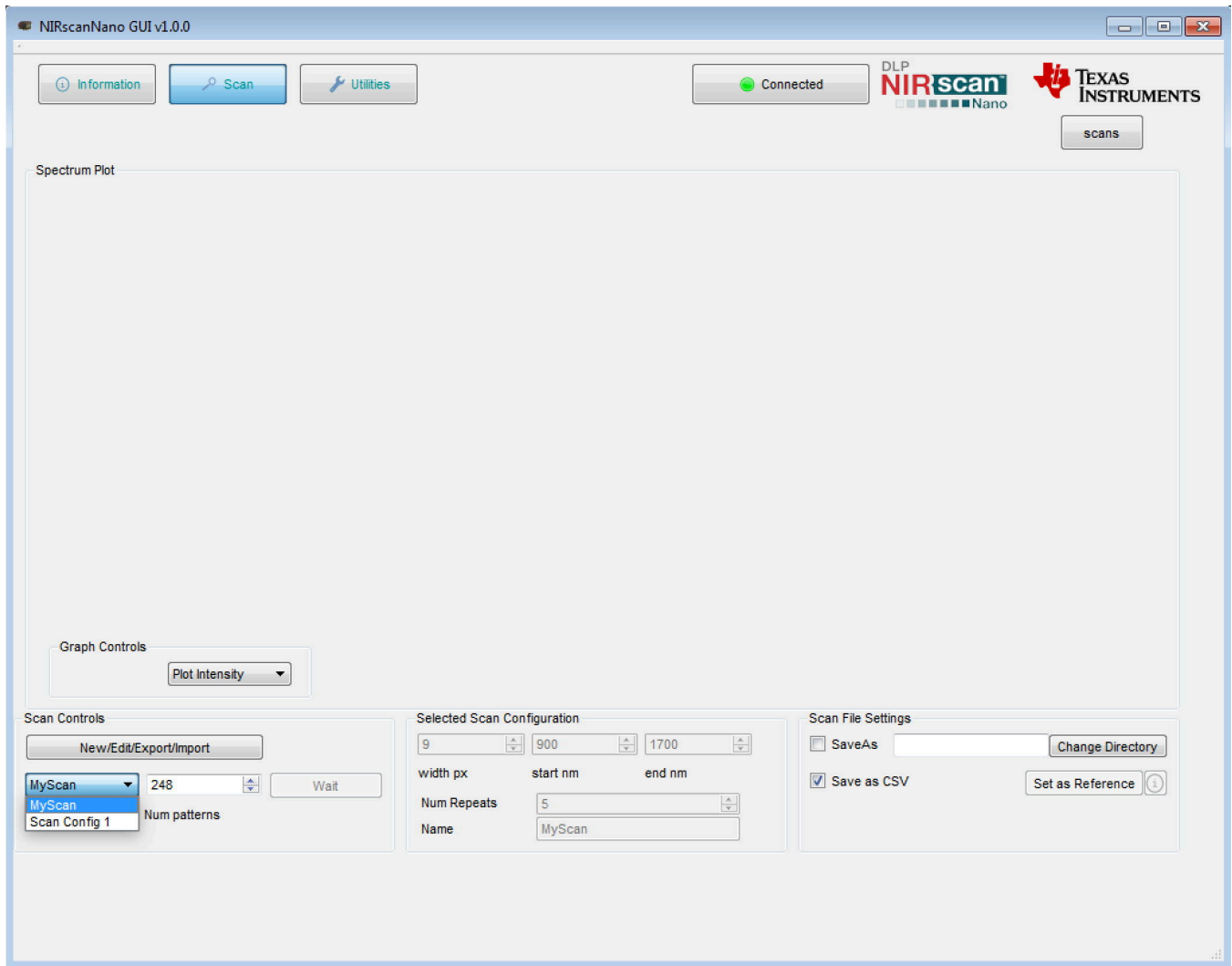


Figure 3-4. DLP NIRscan Nano GUI Scan Select Menu

After a scan configuration is selected with the drop-down, define a reference by scanning a reflective reference standard. Then, click the Set as Reference button. After these steps, scanning any sample will allow the plot of absorbance as shown in [Figure 3-5](#).

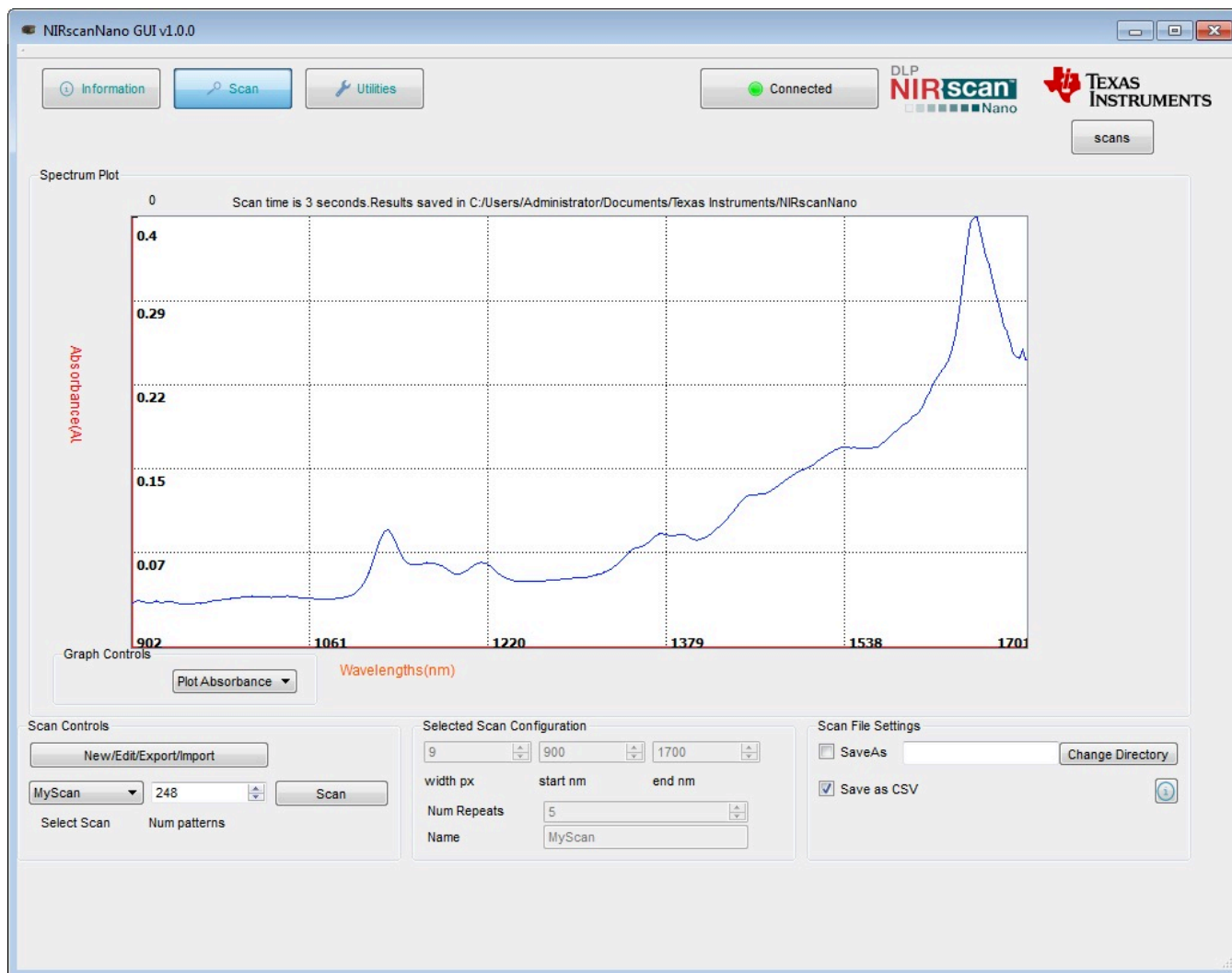


Figure 3-5. Absorbance Spectrum of Aspirin

3.1.2 Displaying Previous Scans

To display previous scans, click the Scans button under the Texas Instruments logo. A sub-window will pop up displaying the previous scans stored in the PC. The files are stored with the name of the scan configuration appended with the date and time of the scan. To plot a file as shown in Figure 3-6, select one of the files and click the Display Spectrum button. Click the Hide button to hide this subwindow.

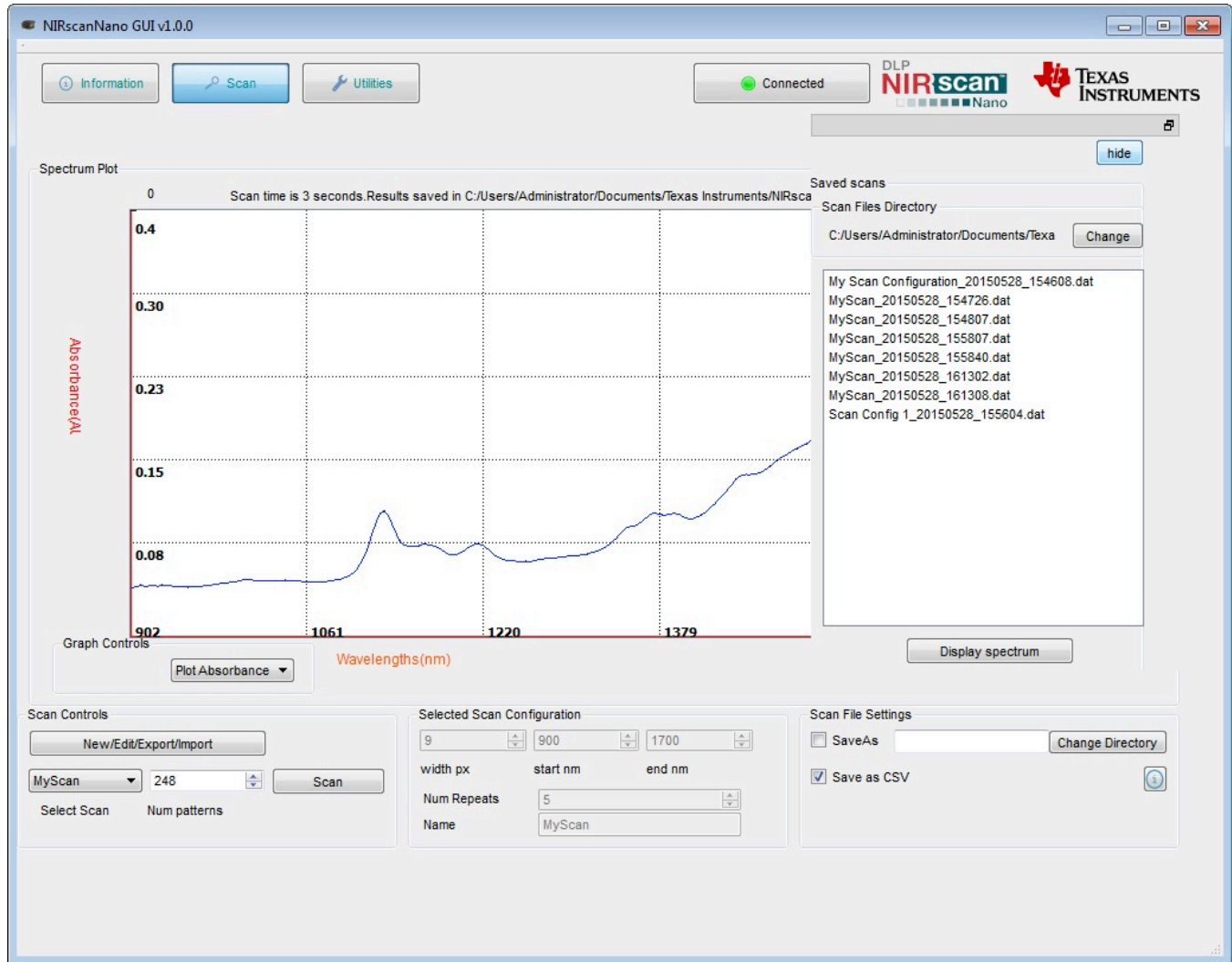


Figure 3-6. Displaying Previous Scans

3.1.3 Transferring Scans Stored in microSD Card

Whenever scans are taken by pressing the Scan button on the microprocessor board, the scans are stored on microSD card, if one is present. To transfer the stored scan on microSD:

- On the Information Tab, under microSD card, click the Refresh button.
- This will read all the scans stored on the microSD card, and will report the number of scans detected after "No. of unread scan Data", as shown in [Figure 3-7](#).
- On the Scan tab, click the Scans button in the upper-right corner to display the previous scans. Scans transferred from the microSD card will be listed with filenames starting with "scan" followed by a four digit number, as shown in [Figure 3-8](#).

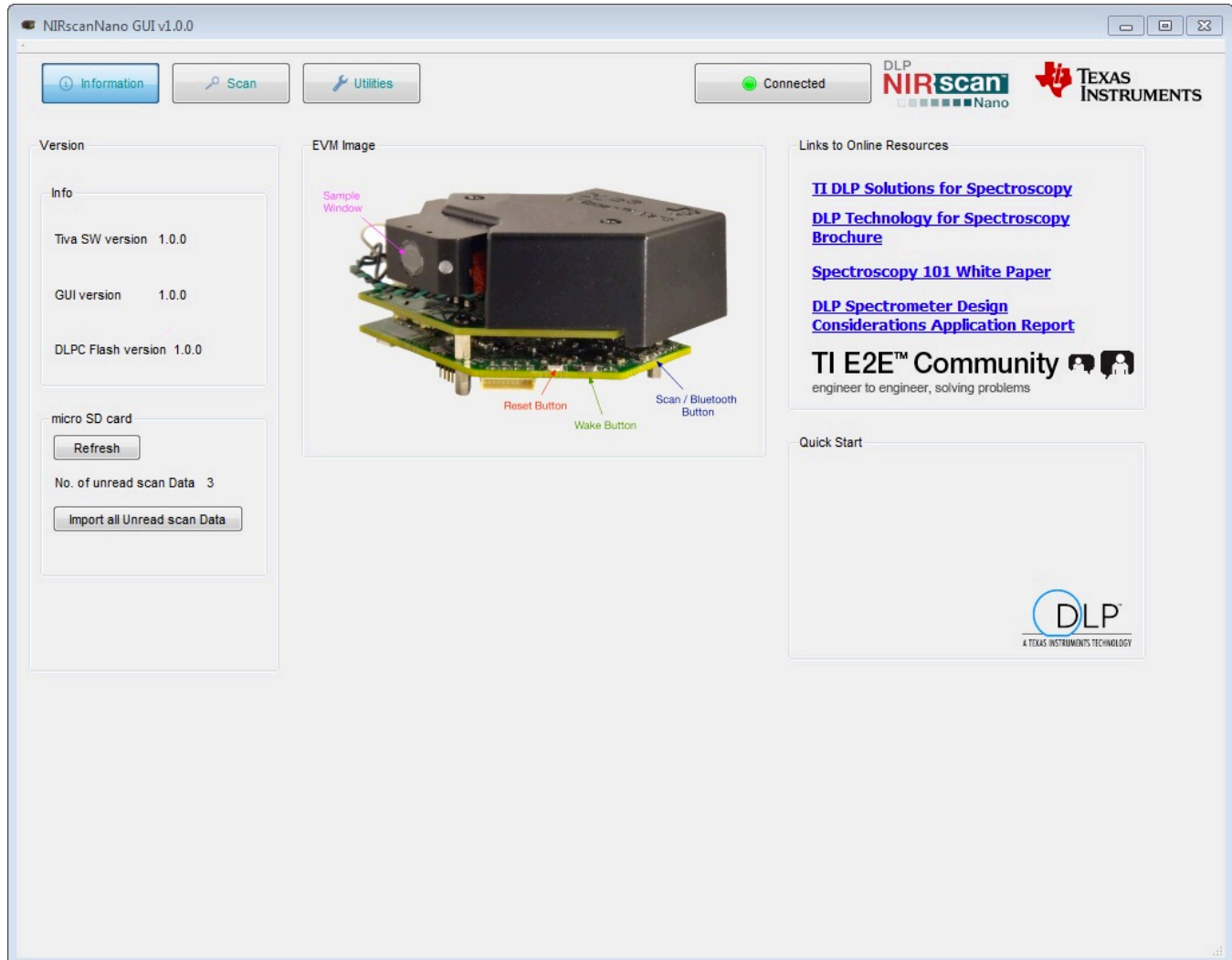


Figure 3-7. Number of Scans Detected on microSD Card

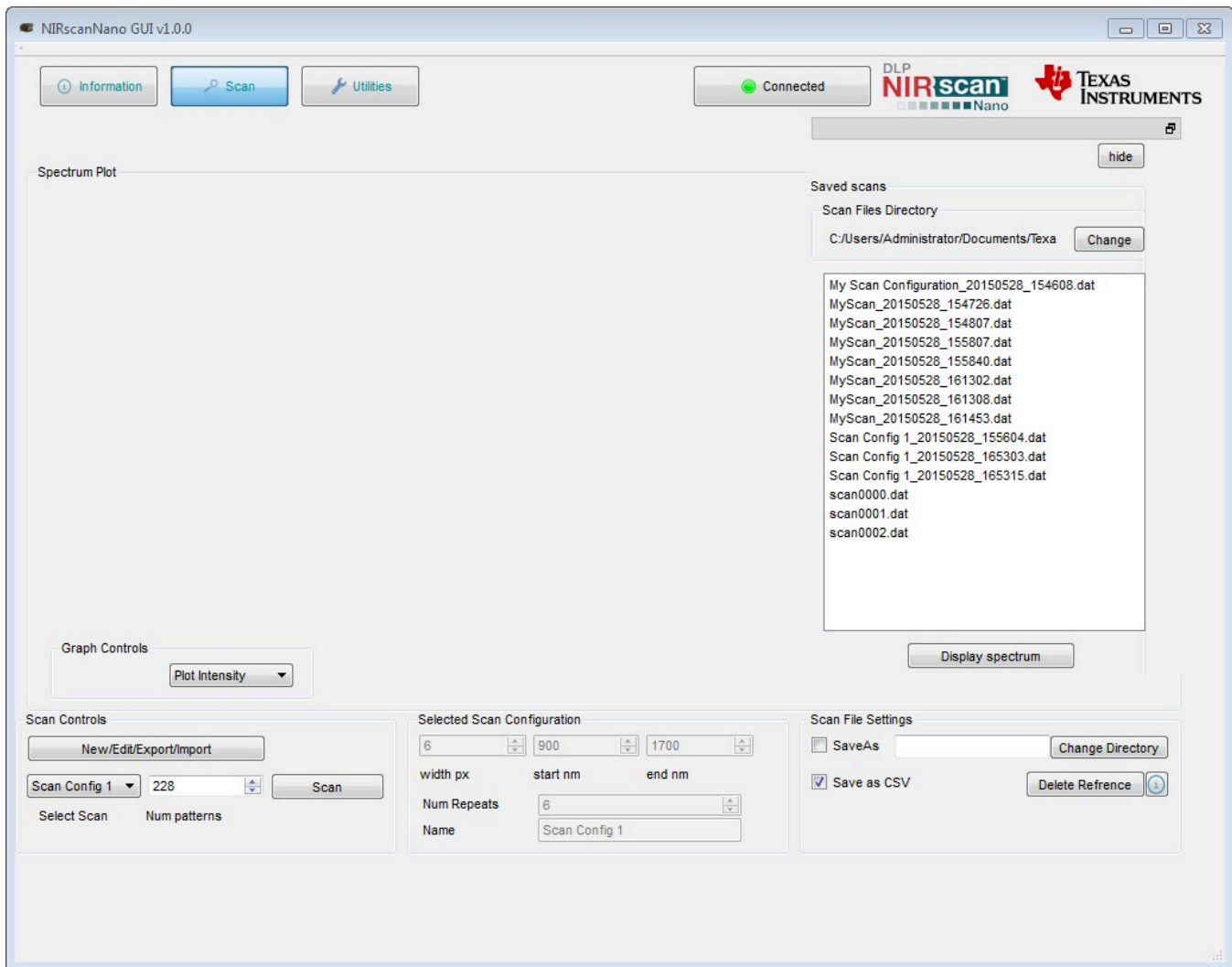


Figure 3-8. 3 Scans Transferred from microSD Card

3.1.4 Utilities

The DLP NIRscanNano GUI includes a Utilities screen, as shown in [Figure 3-9](#), that displays:

- Sensor data:
 - Battery voltage, if a Lithium-Ion or Lithium polymer single cell battery is connected to J6 connector.
 - Ambient temperature read by the TMP006 in the Detector Board.
 - Detector temperature read by the TMP006 in the Detector Board.
 - Ambient humidity read by the HDC1000 in the Microcontroller Board.
 - HDC temperature read by the HDC1000 in the Microcontroller Board.
 - Tiva internal temperature read by the Tiva internal sensor in the microcontroller board.
- Tiva's hibernation module date and time. Pressing the "Sync Data/Time" button will read the PC's date and time and store it in the Tiva hibernation module's date and time registers.
- DLPC150 Firmware update tool.
 - To update the DLPC150 firmware, click the Browse button to search for the DLPC150 firmware file (for example, C:\ti\DLPR150PROM_1.0.0.img).
 - Then, click the Update DLPC150 Firmware button. The firmware will be flashed to the board while

- the progress bar indicates the update process.
- Tiva Firmware update tool.
 - To update the Tiva firmware, click the Browse button to search for the Tiva firmware file (for example, C:\ti\DLPNIRscanNanoSoftware_1.0.0\Binaries\NIRscanNano.bin).
 - Then, click the Update TIVA Firmware button. The firmware will be flashed on the Tiva internal Flash while the progress bar indicates the update process.
- Detector board's ADS1255 PGA setting.

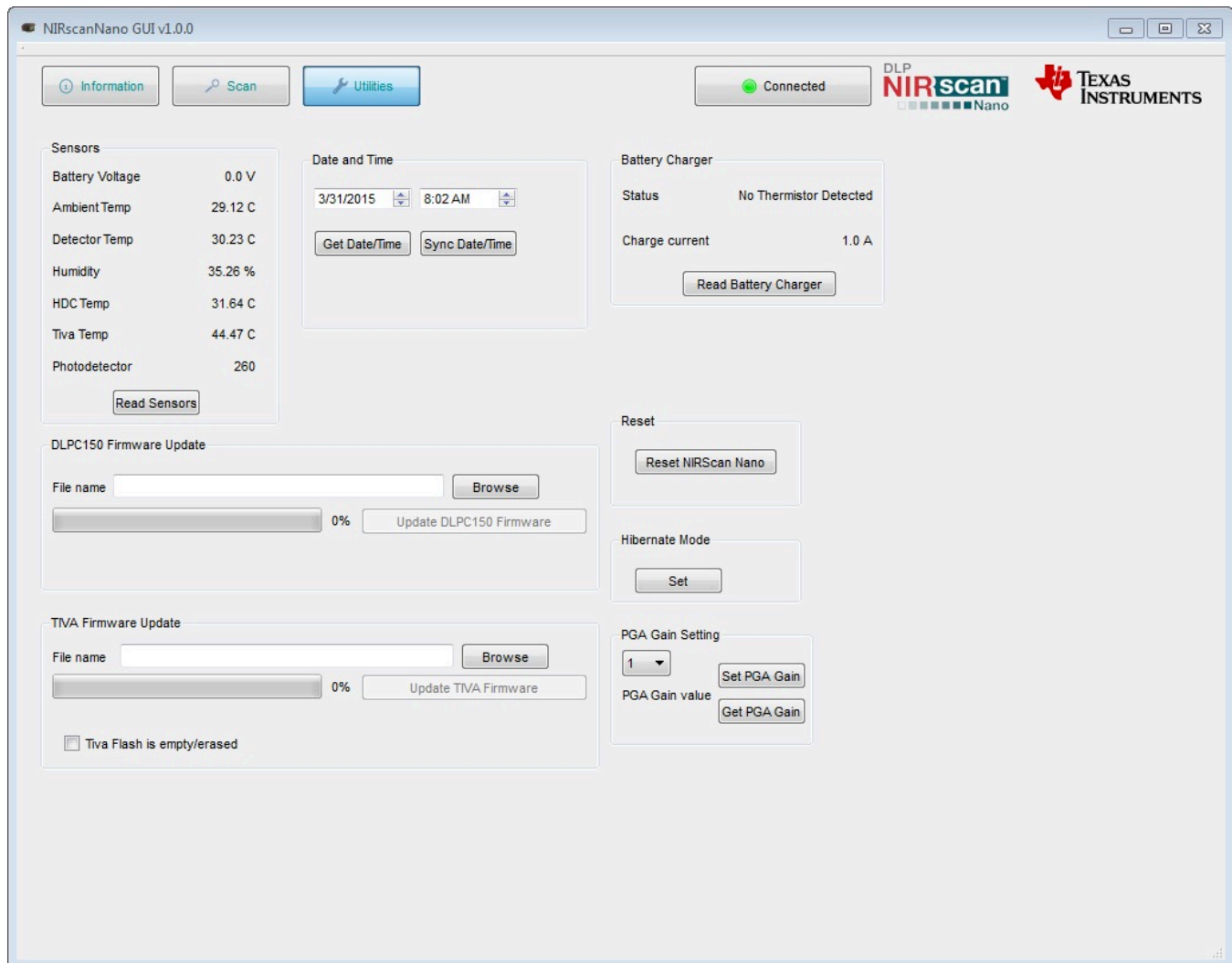


Figure 3-9. DLP NIRscan Nano GUI Utilities Screen

DLP NIRscan Nano Hardware

4.1 External Power Supply Requirements

The DLP NIRscan Nano is powered from either a battery or a USB cable. The power requirements are:

- **USB Cable:**
 - Voltage: 4.75 to 5.25 V
 - Current Maximum: 560 mA when operating and 1 A when charging
 - Cable: 3 ft, USB A male to micro-USB B male (cable not included)
 - Digi-Key Part Number: Q853-ND
 - Manufacturer: Qualtek
 - Part Number: 3025010-03
- **Battery: (Not Included)**
 - Single-Cell Lithium-Polymer UL certified battery
 - Voltage: 3.7 V
 - Capacity: 1700 mA
 - Manufacturer: Tenergy
 - Part Number: 103450

NOTE: Only connect Tenergy 103450 Lithium Polymer UL certified battery or equivalent UL certified battery that meets: maximum charge current of 1A or more, maximum charging voltage of 4.23V or higher, battery over voltage protection at 4.305V or higher, and battery under voltage lockout at 2.5V or less.

If a battery is connected to the NIRscan Nano, a thermistor is required to safely charge the battery and monitor its temperature. The battery thermistor requirements are:

- **Battery Thermistor: (Not Included)**
 - 10-k Ω NTC thermistor
 - Manufacturer: Murata
 - Part number: NXRT15XH103FA1B040
 - Digi-Key part number: 490-7167-ND

Figure 4-1 shows a block diagram of the power circuits. The main power input is the external battery and USB connector. The bq24250 includes a single-cell battery charger and a highly efficient DC-DC converter to regulate the system voltage at 3.52 V. With an optional thermistor, the bq24250 monitors the temperature of the battery during charging. Note that a thermistor is required to charge the battery. The battery charger is set to supply up to a 1-A current during charging.

The rest of the devices regulate power to the subsystem as follows:

- The DLPA2005 in the DLP controller board regulates the power to the DLP2010NIR and DLPC150.
- The TPS82671 in the microcontroller board regulates the 1.8-V supply used by the Bluetooth subsystem CC2564MODN. To conserve power, a TPS22904 load switch turns off the 1.8-V supply to the Bluetooth subsystem when not in used.
- The TPS630636 in the microcontroller board supplies the main 3.3 V for the microprocessor and interface inputs and outputs to DLPC150, CC2564MODN, and Tiva microprocessor.

- The TPS81256 in the microcontroller board regulates the 5-V supply of the analog-to-digital converter (ADS1255), transimpedance amplifiers circuits (OPA350 and OPA2276), and 2.5-V reference voltage (REF5025) used in the detector board.
- A second TPS81256 in the DLP controller board regulates the 5-V supply for the lamp driver (OPA567 and INA213). The lamp driver drives two parallel lamps at 5 V and 280 mA. Each lamp is rated to a maximum 140 mA at 5 V.
- The TPS386596 serves as reset supervisor to hold the system in reset while all the supplies reach operational conditions. An external reset button issues a reset when the system has reached operational conditions.

For detailed connections of these devices, refer to the DLP NIRscan Nano schematics.

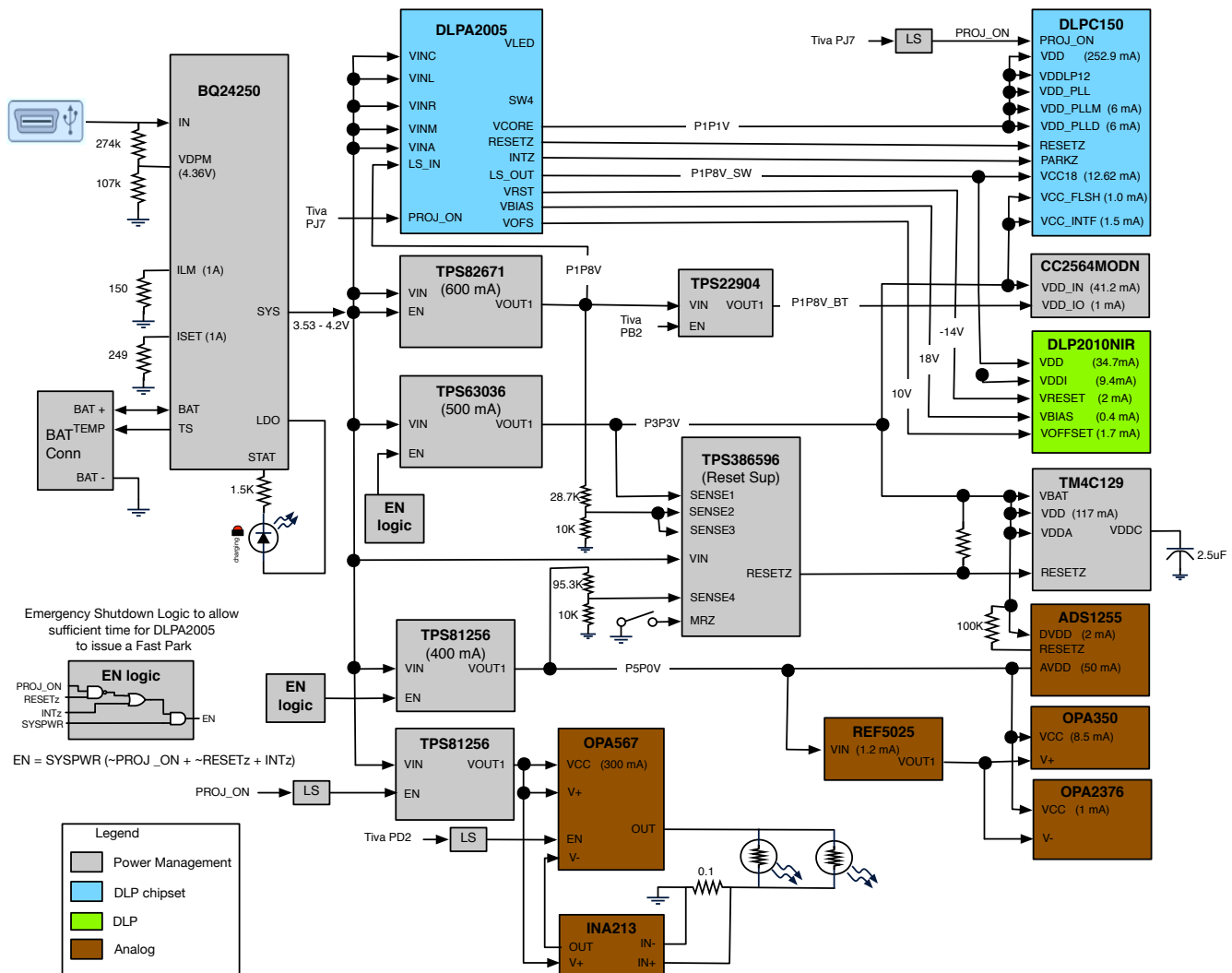


Figure 4-1. DLP NIRscan Nano Power Block Diagram

Figure 4-2 shows the Tiva connections to the components on the microprocessor board and detector board. The Tiva uses a 16-MHz external crystal as input to its on-board PLL to run the Tiva system at 120 MHz. A 32-kHz crystal supplies the clock to the Tiva's hibernation module and Bluetooth circuits. An external 32MB of SDRAM stores the patterns that are streamed to the DLPC150 through the Tiva's LCD interface. Tiva communicates to the HDC1000 and TMP006 sensors through its I2C6 and I2C7 peripherals. Both sensors generate a DRDY signal when a new value is available. This DRDY signals interrupt Tiva when a new value is available through PP7 for HDC1000 and PP6 for TMP006. Tiva's UART3 communicates with the CC2564MODN for Bluetooth transfers. The UART3 defaults to a 115200 baud transfer rate. Tiva's PH5 enables the Bluetooth circuits. Tiva interfaces to the microSD card through

SSI3 in SPI mode. Tiva's SSI1 interfaces to the ADS1255. The ADS1255 also generates a DRDY signal when conversion is completed interrupting the Tiva processor through PP2. Tiva generates a synchronization signal to the ADS1255 through PH6 to start an ADC conversion when a pattern is displayed by the DLP2010NIR. To monitor the battery charger bq24250, PQ5 serves as a Tiva interrupt and commands are sent through I2C9. PQ0, PQ1, and PQ2 allow Tiva to override default bq24250 parameters. The Wake and Scan buttons are connected to Tiva's WAKE and PQ3 pins. To measure battery voltage, Tiva enables an analog MOSFET switch with PD5 to connect the battery to Tiva's ADC and perform a voltage measurement. An expansion headers supports a combination of Tiva SSI0 and UART4 pins. PF5, PH7, PL4 controls the green, blue, and yellow LED, respectively.

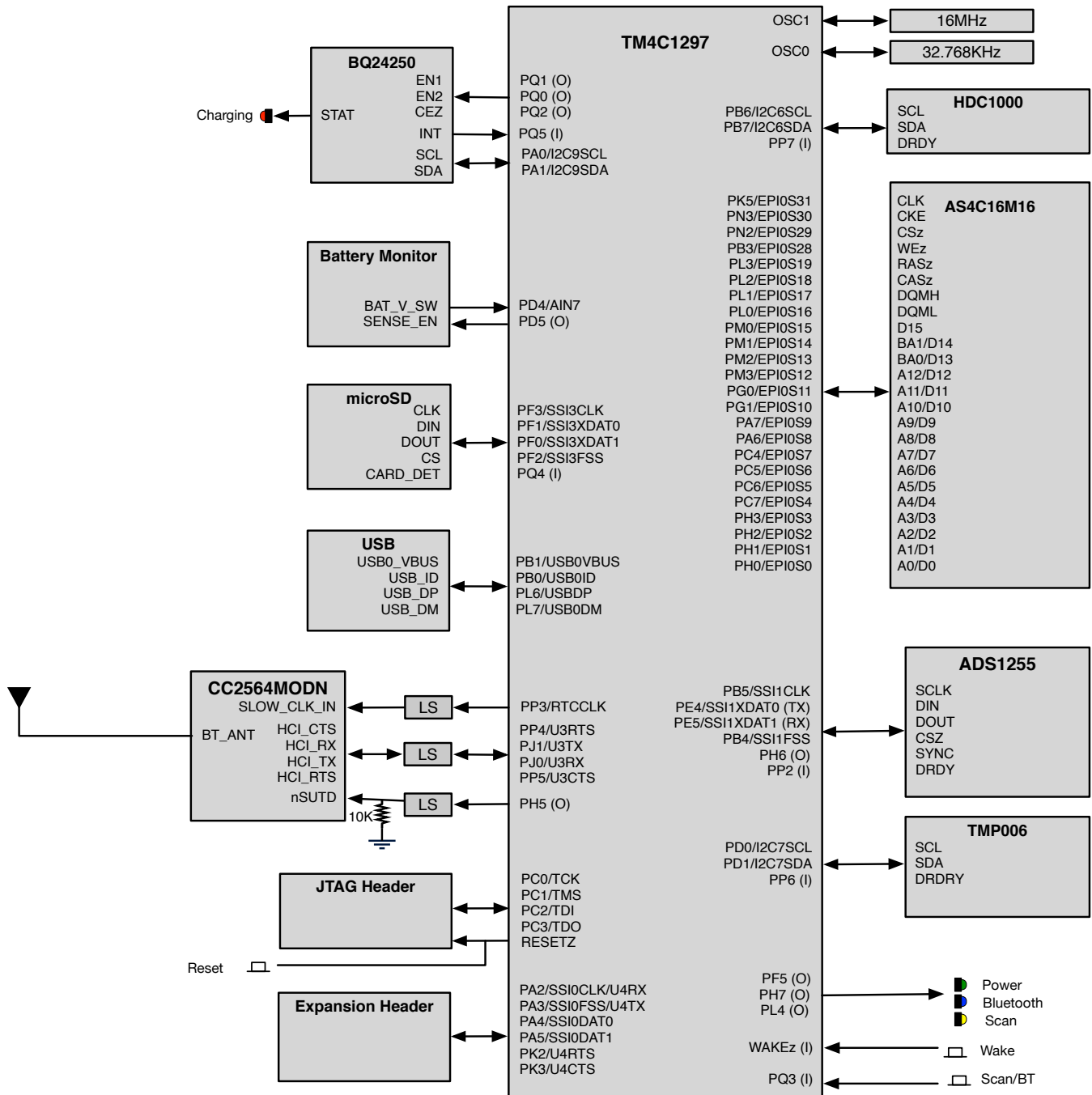


Figure 4-2. DLP NIRscan Nano Tiva Connections

Figure 4-3 shows the Tiva connections to the DLPC150 controller board. Tiva powers up the DLP subsystem through PJ7. The Tiva's LCD interface is connected to the DLPC150 Parallel Port interface. Through this interface 24 patterns are transmitted per frame. DLPC150 sends two interrupts to the Tiva to indicate when a pattern is exposed (TRIG_OUT_2) and when a new frame begins (TRIG_OUT_1). For DLPC150 firmware updates, the Tiva can write to the DLPC150 serial flash through its SSI2 peripheral when the DLP subsystem is powered down. Tiva's PD2 controls the lamp. A lamp photodiode is measured by the DLPA2005 when a scan occurs. The value of the photodiode is transmitted to the DLPC150 and then to the Tiva. This photodiode measures the lamp intensity.

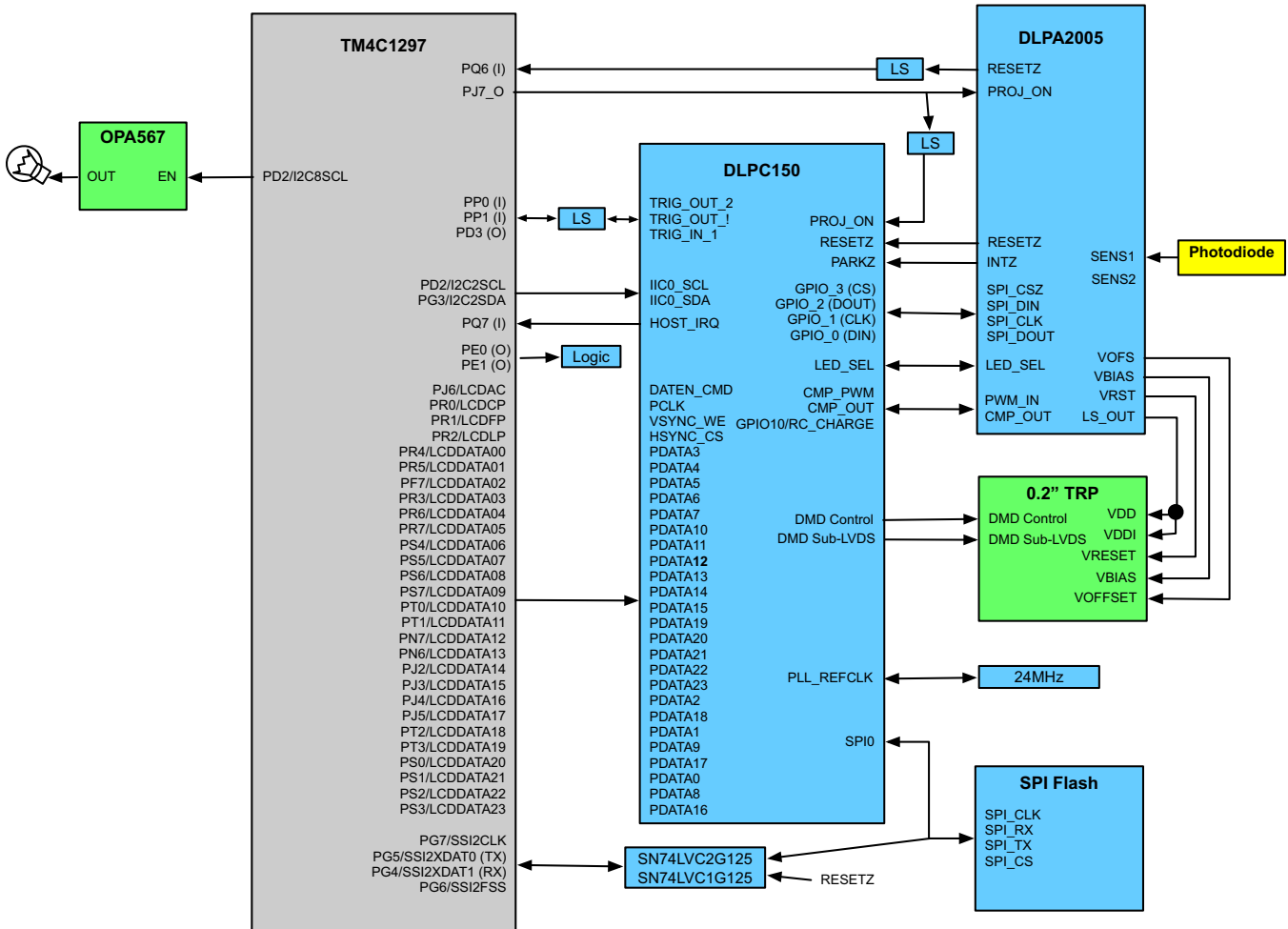


Figure 4-3. DLP NIRscan Nano Tiva Connections to DLPC150 Controller Board

DLP NIRscan Nano Software

5.1 Overview

The DLP NIRscan Nano's Tiva microprocessor is the system's main control processor. The Tiva handles button presses, commands and data transfers over USB or Bluetooth, controls the DLP subsystem, streams the patterns to select specific wavelengths, captures data from InGaAs detector, activates lamps, and stores data in the microSD card. Due to the realtime nature of the system, the Tiva software includes TI-RTOS that coordinates tasks while handling realtime interrupts and semaphores. Low-level drivers for Tiva's USB, GPIO, EPI, I²C, LCD, SPI, and UART peripherals are handled by TivaWare libraries and routines. The Bluetopia Stack handles Bluetooth communications. DLP Spectrum Library handles pattern generation and data transformation from raw scan data to a wavelength spectrum. A command handler interprets commands from USB or Bluetooth and starts the tasks needed to execute the commands. The main application initializes the system and waits for commands from USB and Bluetooth. The overall software architecture depicting these components is shown in [Figure 5-1](#).

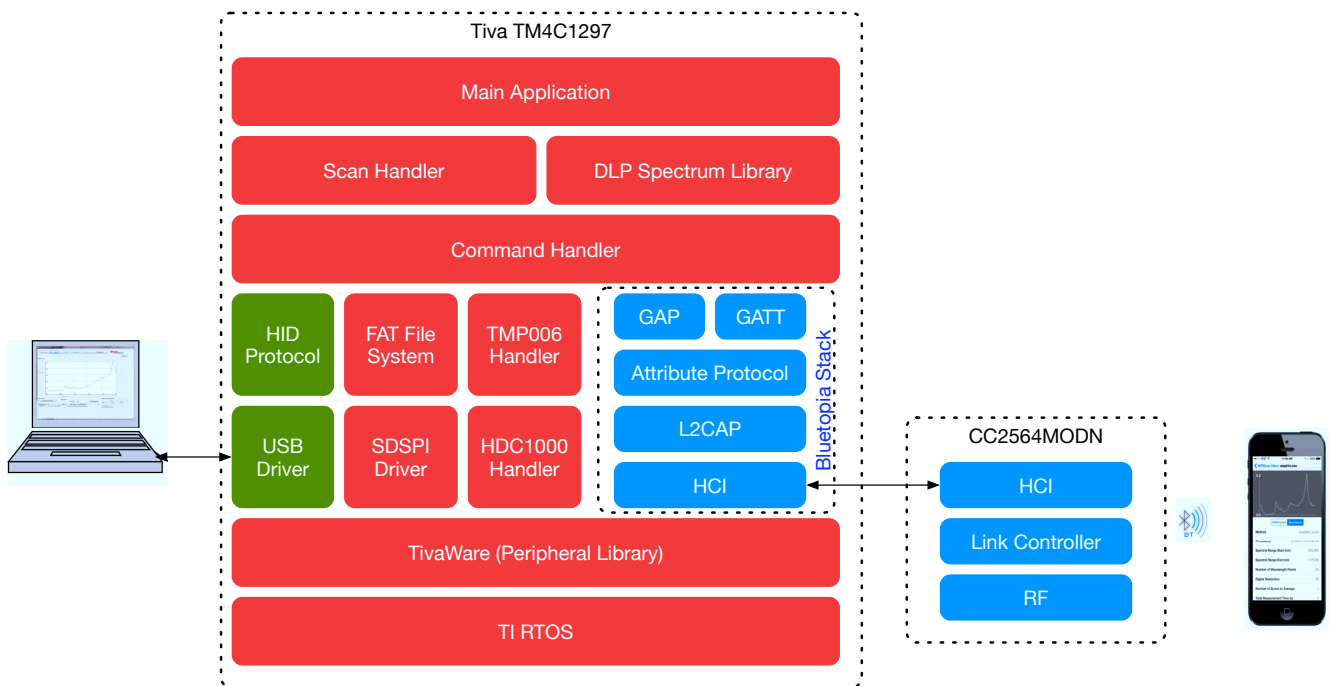


Figure 5-1. DLP NIRscan Nano Software Architecture

5.1.1 TI RTOS

TI RTOS is a scalable, real-time operating system that handles scheduling and synchronization of tasks, interrupts, includes a limited set of drivers, and provides hardware abstraction layer to ease application software development. The TI RTOS also includes the FAT file system (FATFs) module to store data in the microSD card. The TI RTOS drivers used by DLP NIRscan Nano are:

- I²C: driver used for Tiva communication with DLPC150, TMP006, and HDC100.
- SDSPI: SPI driver for Tiva communication with SDCard.
- USBMSCHFatFS: driver for USB mass storage class.

5.1.2 TivaWare

TivaWare is a set of drivers for accessing the Tiva peripherals. DLP NIRscan Nano uses the following TivaWare drivers:

- UART: Driver for Tiva interface with CC2564MODN
- USB: Driver for HID transfers between Tiva and PC. The USB drivers handles Tiva's USB interrupts
- SPI: Driver for Tiva interface with ADS1255
- ADC: Driver to control Tiva ADC peripheral
- GPIO: Driver to control Tiva GPIO pins
- LCD: Driver to interface Tiva with DLPC150 parallel port

5.1.3 USB Driver

USB Communication to the DLP NIRscan Nano uses the HID class. Tiva enumerates as a slave USB 2.0 high power device. [Appendix G](#) lists the commands supported through USB.

5.1.4 SDSPI Driver

To store data on the microSD card, Tiva's SSI3 peripheral communicates with the microSD card using SPI mode (SDSPI). Tiva stores data on the microSD card using the file allocation table (FAT) file system.

5.1.5 **Bluetopia Stack**

The DLP NIRscan Nano wirelessly communicates using Bluetooth Low Energy (BLE) version 4.0. The Bluetooth communication is handled by the TI Bluetopia stack and the Cc2564MODN. The TI Bluetopia stack and CC2564MODN implement a fully certified Bluetooth 4.0 specification. **The BLE wireless communication uses two main profiles for discovery and communication with a remote host:**

- GAP: Generic Access Profile for basic discovery and establishing connections.
- GATT: Generic Attribute Profile for commands and data transfer.

The DLP NIRscan Nano supports Bluetooth version 4.0 specification. When Bluetooth subsystem is activated, **the DLP NIRscan Nano broadcasts its availability while a smartphone, tablet or PC acts as an observer. Once connected, the DLP NIRscan Nano acts as a server for the GATT profile while the smartphone, tablet, or PC acts as a client.**

The DLP NIRscan Nano Bluetooth GATT Profile supports the following services:

- Battery Service (BAS) to provide battery charge capacity.
- Device Information Service (DIS) to provide manufacturer name, model number, serial number, hardware revision, spectrum library revision, and Tiva software revision.
- GATT General Information Service to provide temperature, humidity, status, hours of use, lamp hours, and battery recharge cycles.
- GATT Date and Time Service to synchronize date and time information between smartphone, tablet, or PC to the Tiva's realtime clock.
- GATT Calibration Service to provide calibration coefficients.
- GATT Scan Configuration Service to provide stored configurations and scan configuration data.
- GATT Scan Data Service to initiate scan, clear scan data, and return stored scan data.

The Tiva processor handles these profiles and uses the logical link control and adaptation protocol (L2CAP) to pass packets through a host controller interface (HCI). The Tiva's UART3 peripheral communicates with the CC2564MODN HCI module. The CC2564MODN transmits these packets to the client device.

5.1.6 DLP Spectrum Library

The DLP spectrum library is a collection of C-language routines that provide the fundamental pieces to use a DLP system in a spectroscopy application. The DLP spectrum library is resolution and host processor independent, allowing the routines to be used with different DMD resolutions and processor systems. The routine sources are shared by the Tiva code, the GUI code, and the iOS App. The DLP Spectrum Library are classified into three main categories:

- **Scan:** Performing a column or Hadamard scan by:
 - Generating the appropriate full-frame DMD patterns based on a specific scan configuration.
 - Computing reflectance and absorbance data from the intensity data during a scan.
 - Handling serialization and deserialization of scan configuration and scan data.
- **Calibration:** Calibrating a system at the factory by:
 - Finding peaks from a scan of a calibrated lamp.
 - Finding the full width half maximum of specific peaks data of a calibration scan.
 - Computing the calibration coefficients for a system.
- **Utilities:** Utilities to handle:
 - Conversion between DMD mirror column position to a calibrated wavelength or wave number, and vice versa.
 - Spectrum data calculations, such as: absorbance, reflectance, and spectrum comparisons.
 - Matrix operations.
 - Binary pattern packing.

The DLP NIRscan Nano utilizes a previously-created scan configuration (through the GUI or stored on the NIRscan Nano) to perform a scan. This scan configuration is created on the NIRscanNanoGUI and transferred to the system in serialized fashion. The system's Tiva processor deserializes this data and generates a set of full-frame DMD patterns based on the scan configuration and the factory-stored calibration data. Then, the Tiva turns on the lamps and streams the full-frame DMD patterns to perform a scan. Tiva collects several data points for each pattern from the detector's ADC conversion. This data is stored in a structure, and is then serialized and transferred to the PC through USB or Bluetooth. The NIRscanNanoGUI or the iOS App deserializes this scan data, interprets it using the DLP Spectrum Library, and plots the resulting spectrum.

5.1.7 DLP Spectrum Library Workflow

The following sections show the use of the DLP Spectrum Library workflow to read scan configuration information, decode scan data, and compute reference, absorbance, and reflectance.

5.1.7.1 Scan Configuration Workflow

The DLP Spectrum Library routine to interpret scan configuration information is **dplspec_scan_read_configuration()**. This routine takes as input the serialized scan configuration transferred through USB or Bluetooth and deserializes to extract all the scan configuration information. [Figure 5-2](#) shows the typical workflow to view configuration information. The white input box denotes USB scan configuration data, while the blue input box denotes Bluetooth scan configuration data.

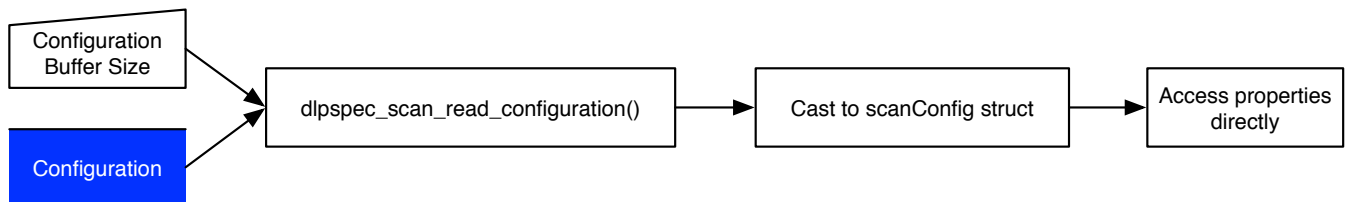


Figure 5-2. DLP Spectrum Library View Configuration Information Workflow

5.1.7.2 Decode Scan Workflow

The DLP Spectrum Library routine to interpret scan data is `dlp_scan_interpret()`. This routine takes as input the serialized scan data transferred through USB or Bluetooth and deserializes and extracts the intensities of each wavelength in a scan. Figure 5-3 shows the typical workflow to decode scan data. The white input box denotes USB scan data, while the blue input box denotes Bluetooth scan data.

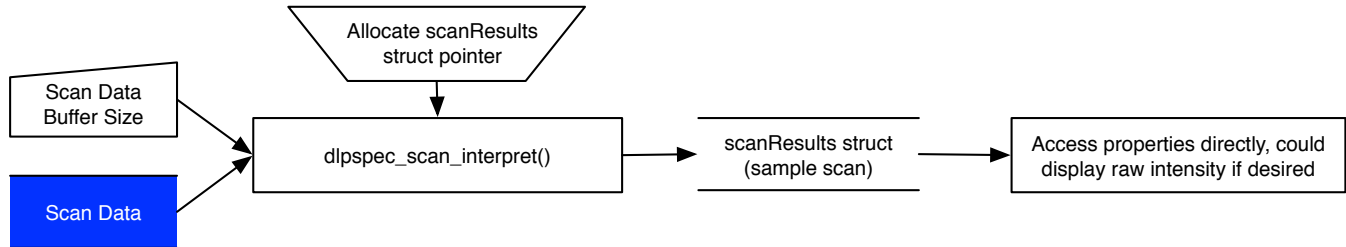


Figure 5-3. DLP Spectrum Library Decode Scan Results Workflow

5.1.7.3 Compute Reference Workflow

The DLP Spectrum Library routine to compute reference is `dlpspec_scan_interpReference()`. This routine takes as input the serialized reference calibration data stored on the DLP NIRscan Nano and transmitted through Bluetooth or the stored reference on the PC transmitted through USB and computes the reference intensities for each wavelength in a scan. Figure 5-4 shows the typical workflow to compute the reference. The white input box denotes USB reference data, while the blue input box denotes Bluetooth reference calibration data.

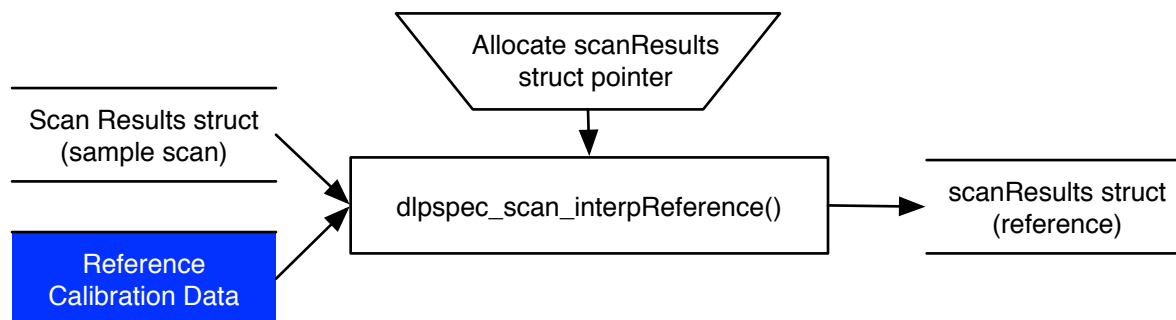


Figure 5-4. DLP Spectrum Library Compute Reference Workflow

5.1.7.4 Compute and Display Reflectance Workflow

The DLP Spectrum Library computes the reflectance of a scan based on the scan intensities divided by the reference scan. Figure 5-5 shows the typical workflow to compute the reflectance.

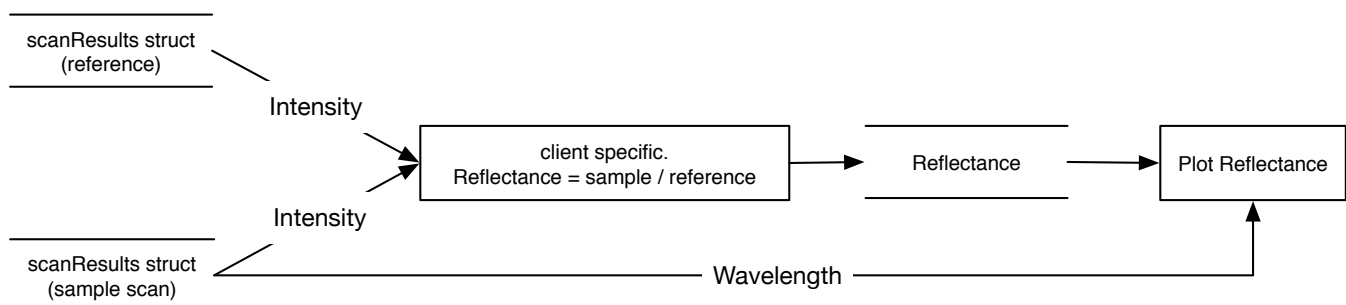


Figure 5-5. DLP Spectrum Library Compute and Display Reflectance Workflow

5.1.7.5 Compute and Display Absorbance Workflow

The DLP Spectrum Library computes the absorbance of a scan based on the negative of the logarithm (based 10) of the reflectance. [Figure 5-6](#) shows the typical workflow to compute the reflectance.

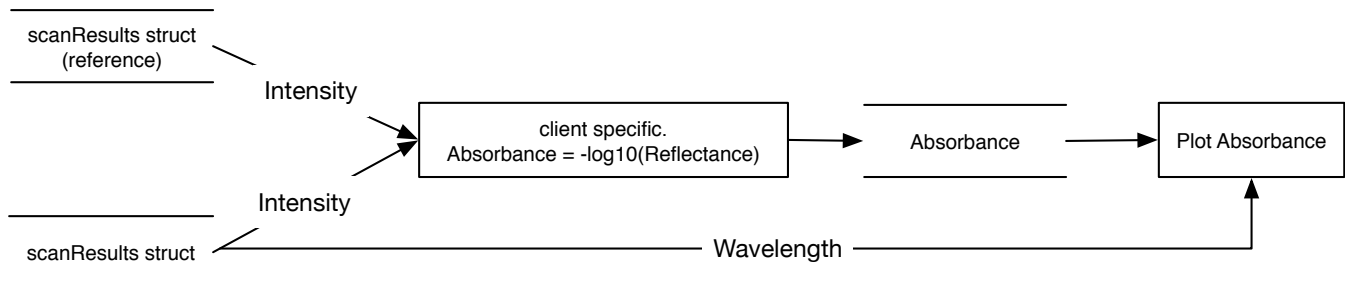


Figure 5-6. DLP Spectrum Library Compute and Display Absorbance

5.2 Software System Overview

The DLP NIRscan Nano software uses a sets of tasks, hardware interrupts, and semaphores to coordinate the efforts needed to interpret USB or Bluetooth commands, respond to button presses, scan an object, and capture the InGaAs detector values. [Figure 5-7](#) shows a high-level block diagram of the software elements of the system. The DLP NIRscan Nano system includes the following hardware interrupt handlers to respond to hardware events:

- Button Interrupt Handler: Responds to Scan/Bluetooth button presses and Wake button presses.
- Trigger Interrupt Handler: Synchronizes and keeps track of the pattern displayed during a scan. Two interrupts from the DLPC150 (ihFrameTrigger and ihPatternTrigger) indicate when a pattern has been displayed, when 24 patterns have completed the display, and when the DLPC150 buffer needs to be reloaded with new patterns. This handler also captures data from the ADS1255 when a pattern is displayed. It uses the ADS1255 DRDY signal to trigger the read of the just-converted value.
- Display Interrupt Handler: Controls the Tiva LCD peripheral and its frame buffer that resides in external SDRAM. The frame buffer streams 24 patterns per frame to the DLPC150.

The following tasks handle specific portions of the system:

- USB driver: This task is part of the TivaWare USB driver and handles all USB HID transactions. The data from USB transactions is passed to the command handler task to interpret and respond to a specific set of USB commands described in [Appendix G](#).
- **Bluetooth Stack**: This task handles Bluetooth communication with a mobile application through the implementation of GATT profile in the Bluetopia Stack. Several semaphores control the operation:
 - BLEStartSem: Power-up the Bluetooth circuits and initializes the Bluetooth Stack.
 - BLEEndSem: Powers-down the Bluetooth circuits and gracefully closes the Bluetooth Stack.
 - BLECmdRecd: Coordinates the reception and processing of GATT profiles and notifies Command Handler of a new command to be processed.
 - BLECmdCom: Handles the response to a BLE Client's read and notify requests.
 - BLENotifySem: Handles the asynchronous notifications to a BLE Client's notification subscriptions.
- Command Handler: Interfaces the USB and Bluetooth tasks, interprets commands, and starts the sensor read task and the scanning tasks.
- Scan Handler: Controls power to the subsystems necessary to perform a scan (ADS1255, Lamp, DLPC150), manages the pattern streamed to the DLPC150, and reads sensor information during a scan. Two semaphores control the start of the scan (scanSem) and the end of a scan (endscanSem).
- TMP Handler: Manages the temperature readings from the TMP006.
- HDC Handler: Manages humidity and temperature readings form the HDC1000.
- microSD Handler: Controls reading and writing data to the microSD card through a FAT32 file system. A semaphore (sdSem) triggers data access to the microSD card.

- Idle Task: Manages the blinking of the LED and UART console transmissions to the expansion connector.

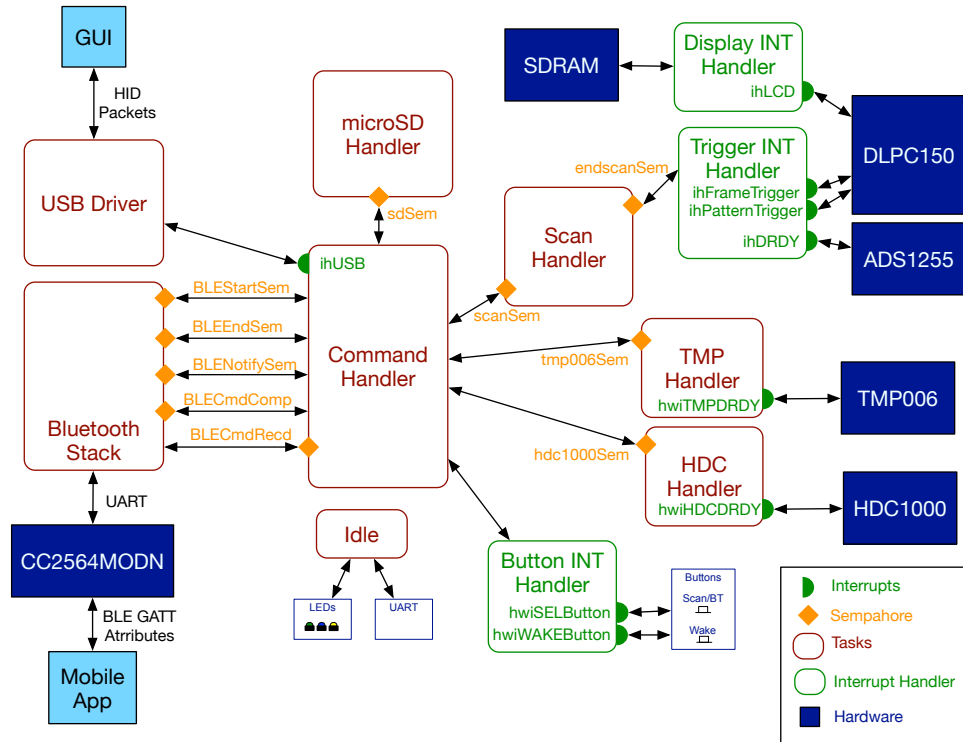


Figure 5-7. DLP NIRscan Nano Software Block Diagram

5.3 Bluetooth Client App Workflow

The following sections describe a suggested workflow for the Bluetooth Client to connect and transfer data.

5.3.1 Bluetooth Client Establishing a Connection

The Bluetooth Client searches for the DLP NIRscan Nano using the GAP for discovery. Once the Bluetooth Client detects a DLP NIRscan Nano, the Bluetooth Client reads the DLP NIRscan Nano advertized packets, establishing a connection. Figure 5-8 describes this process.

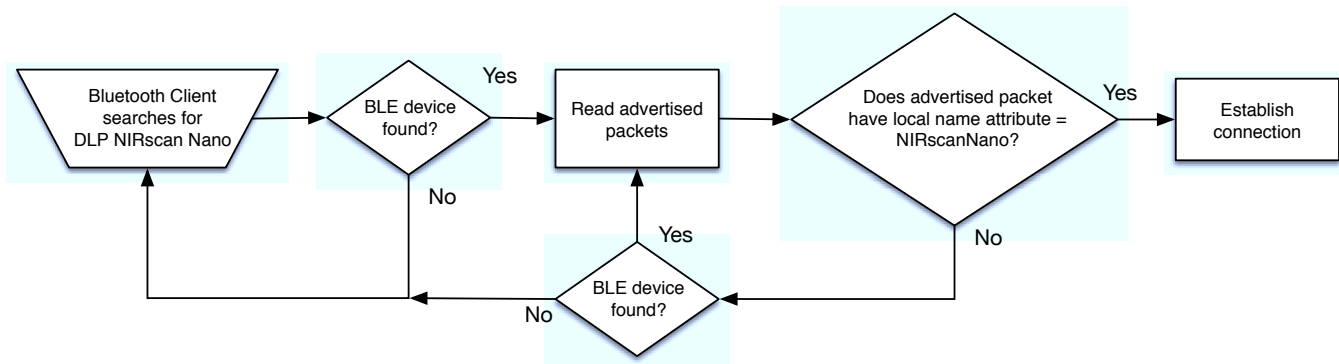


Figure 5-8. Bluetooth Low Energy Connection Workflow

5.3.2 Bluetooth Client GATT Profiles

Once the Bluetooth Client establishes a connection with the DLP NIRscan Nano, the supported GATT profile is enumerated. DLP NIRscan Nano uses standard Bluetooth Low Energy services for Device Information (DIS) and Battery (BAS). The rest of the data transfer is through the custom GATT services and characteristics in the following sections. In the following workflow figures, blue denotes a GATT service characteristic, while red denotes a DLP Spectrum library routine.

5.3.2.1 Bluetooth Client GATT General Information Service

Once the GATT General Information Service is enumerated, the Bluetooth Client can prompt DLP NIRscan Nano to read temperature and humidity values. The Bluetooth Client can set a threshold for temperature and humidity and then subscribe to the temperature and humidity threshold notification. The Bluetooth Client can also read a device and error status and then subscribe to the device and error status notifications.

5.3.2.2 Bluetooth Client GATT Date and Time Service

Once the GATT Date and Time Service is enumerated, the Bluetooth Client can write the data and time values to the DLP NIRscan Nano. It is recommended that the Bluetooth Client sets the date and time every time a connection is established, so the scan data has the correct date and time stamp.

5.3.2.3 Bluetooth Client GATT Calibration Service

Once the GATT Calibration Service is enumerated, the Bluetooth Client can prompt DLP NIRscan Nano to download spectrum calibration coefficients, reference calibration coefficients, and reference calibration matrix. These parameters are unique for each DLP NIRscan Nano and are required for spectrum intensity, reflectance, and absorbance plots. These parameters must to be downloaded whenever a new DLP NIRscan Nano is connected to a Bluetooth Client and before a scan is performed. To download these parameters, the Bluetooth Client must follow these steps:

- Subscribe to the notification of the characteristic UUID that returns the corresponding coefficient.
- Issue a request for the coefficient and wait for the notification to read the corresponding coefficient.
- Once a notification is received, then the Bluetooth Client reads the serialized multiple packets from DLP NIRscan Nano.

Figure 5-9 shows the workflow for this service.

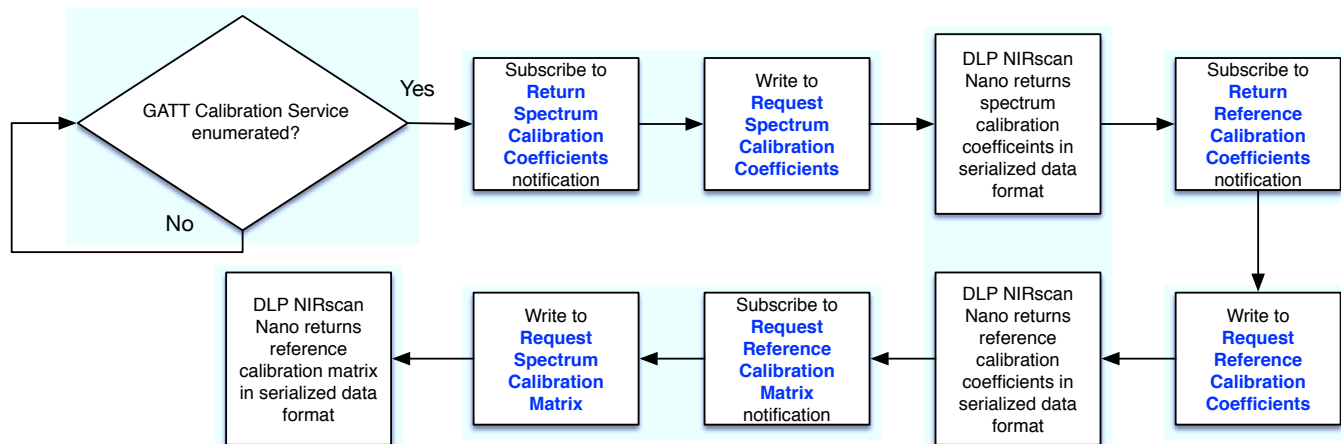


Figure 5-9. GATT Calibration Service Workflow

5.3.2.4 Bluetooth Client GATT Scan Configuration Service

Once the GATT Scan Configuration Service is enumerated, the Bluetooth Client can prompt DLP NIRscan Nano to download stored scan configurations. These parameters must to be downloaded whenever a new DLP NIRscan Nano is connected to a Bluetooth Client and before a scan is initiated. To read the stored scan configuration, the Bluetooth Client must perform the following steps:

- Read the number of stored configurations.
- Subscribe to the notification of the characteristic that returns stored configuration list.
- Issue a request for stored configuration list and wait for the notification to read the stored configuration list.
- Subscribe to the notification of the characteristic that returns scan configuration data.
- Read each scan configuration data by writing the scan configuration ID to the characteristic that returns the scan configuration data, wait for the notification, and then read the serialized scan configuration data returned. The DLP Spectrum Library provides a routine to interpret this serialized data: `dlpspec_deserialize`. Repeat this step for each stored scan configuration.
- Set the active scan configuration by writing to the scan configuration ID to the active scan configuration characteristic.

Figure 5-10 depicts the workflow for this service.

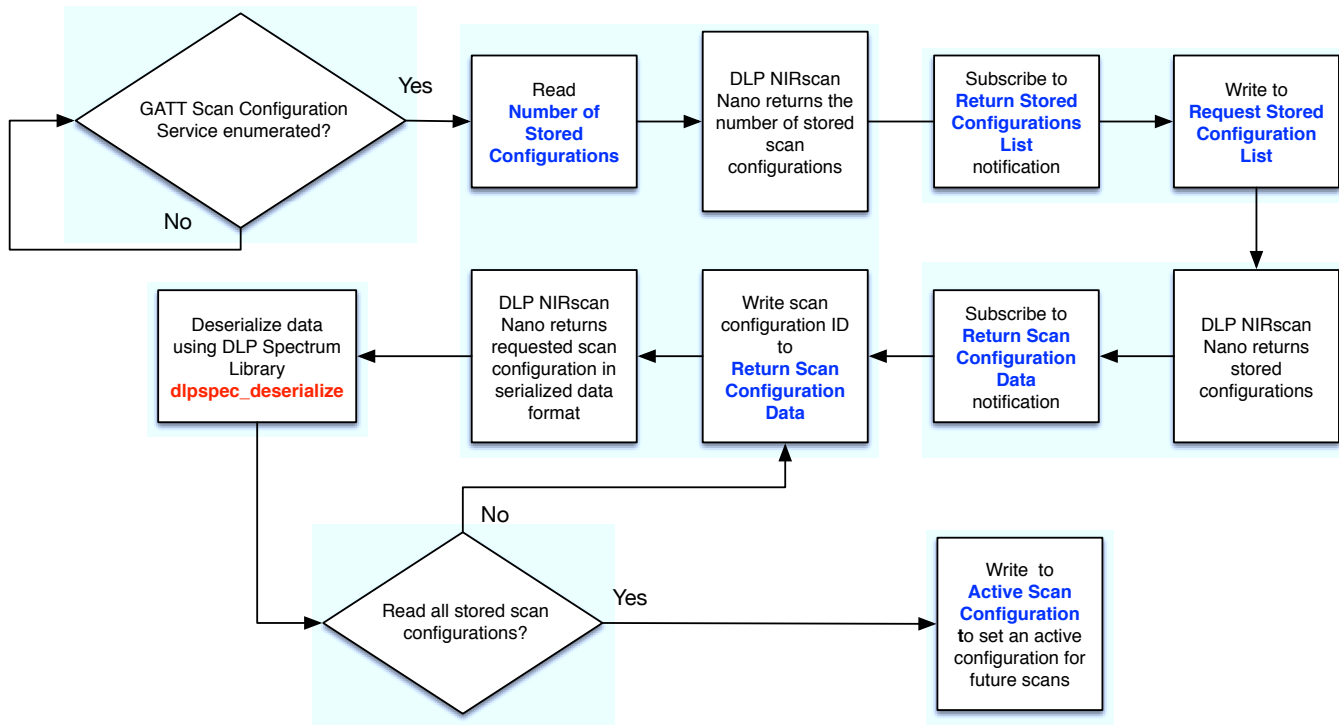


Figure 5-10. GATT Scan Configuration Service Workflow

5.3.2.5 Bluetooth Client GATT Scan Data Service

Once the GATT Scan Data Service is enumerated, the Bluetooth Client can prompt DLP NIRscan Nano to download stored scan data or perform a scan. To read the stored scan data, the Bluetooth Client must perform the following steps:

- Read the number of stored scans.
- Subscribe to the notification of the characteristic that returns stored scan indices list.
- Issue a request to read stored configuration list, wait for the notification to read the stored configuration list.

- Subscribe to the notifications of the characteristics to return scan name, scan type, and scan date/time, and to request packet format version.
- Issue requests for scan name, scan type, scan date/time, and packet format version. Then wait for the notifications to read scan name, scan type, scan date/time, and packet format version. Repeat the last two steps for each stored scan.

To perform a scan, the Bluetooth Client must perform the following steps:

- To display an existing scan:
 - If the scan information is not available, subscribe to the notification of the characteristic to return serialized scan data structure.
 - Issue a request to read serialized scan data structure and wait for the notification to read the scan data structure. The DLP Spectrum Library provides a routine to interpret this serialized data: **dlpspec_scan_interpret**.
- To initiate a scan:
 - Subscribe to the notification of the characteristics to start scan.
 - Issue a request to start scan and wait for the notification that indicates the scan completed.
 - Subscribe to the notifications of the characteristics to return scan name, scan type, and scan date/time, and to request packet format version.
 - Issue requests for scan name, scan type, scan date/time, and packet format version. Then wait for the notifications to read scan name, scan type, scan date/time, and packet format version.
 - Subscribe to the notification of the characteristic to return serialized scan data structure.
 - Issue a request to read serialized scan data structure and wait for the notification to read the scan data structure. The DLP Spectrum Library provides a routine to interpret this serialized data: **dlpspec_scan_interpret**.
- To delete stored scan data:
 - Subscribe to the notification of the characteristic to clear scan.
 - Issue a request to clear scan and wait for the notification that indicates the clear scan completed.

Figure 5-11 and Figure 5-12 show the workflow for this service.

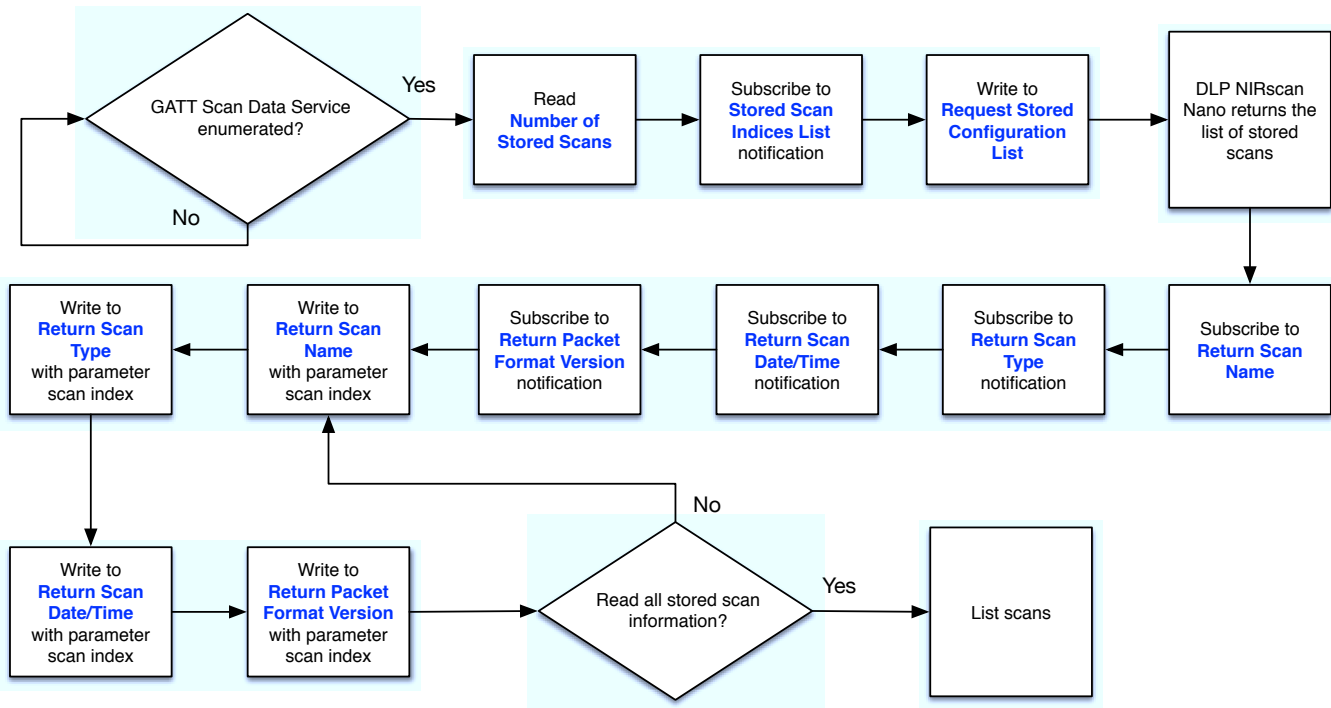


Figure 5-11. GATT Scan Data Service Workflow

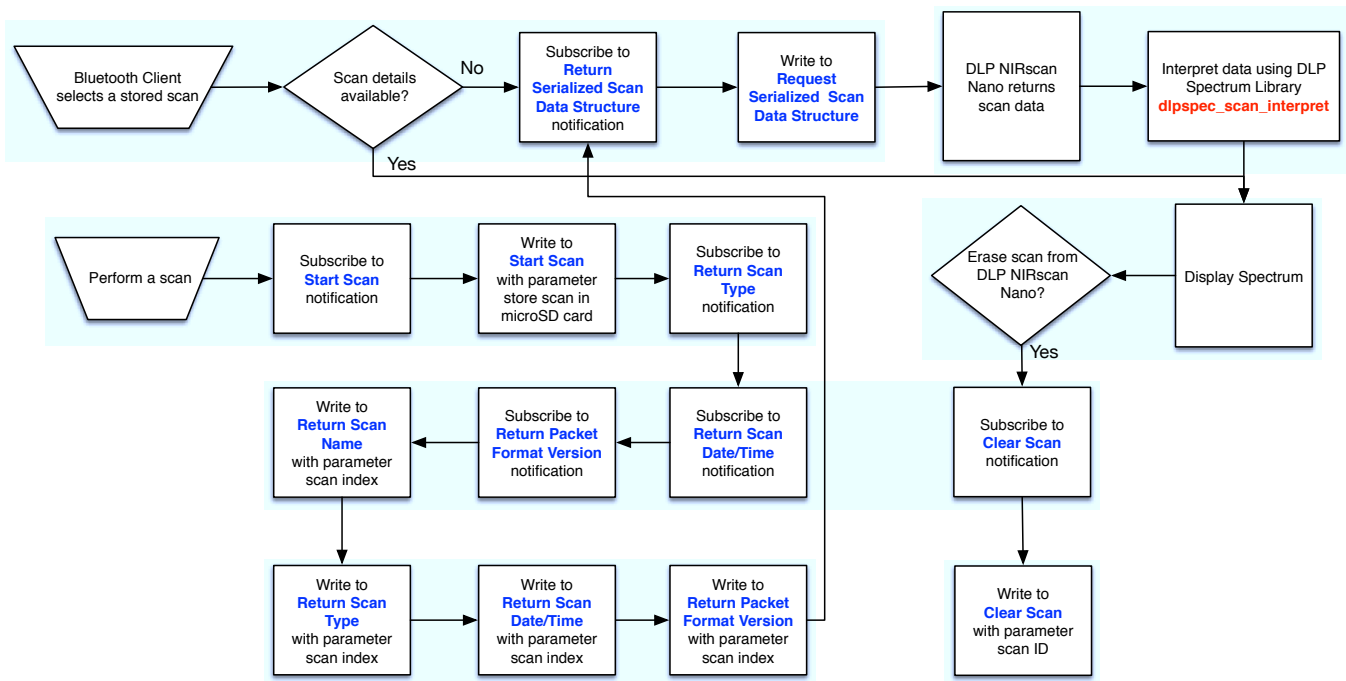


Figure 5-12. GATT Scan Data Service Workflow to Display an Existing Scan or Performing a New Scan

6.1 NanoScan iOS App

[KS Technologies](#) has developed an example iOS app that controls the DLP NIRscan Nano EVM. This app is available for download through the Apple App Store free of charge. This app supports BLE iOS devices: iPhone 4S or later and iPad 3 or later with iOS 7.1 or later.

After running the NanoScan iOS App, the main screen shown in [Figure 6-1](#) lists the previous scans performed with the NIRscan Nano EVM. To connect to a NIRscan Nano EVM, enable the Bluetooth by pressing and holding the scan button on the EVM for more than three seconds. The blue LED will light up to indicate that the Bluetooth circuits are powered and actively scanning. Press Scan on the top-right corner of the iOS App to initiate a connection. The Bluetooth icon in the top-right corner of the iPhone screen will blink as the connection is established. The NIRscan Nano EVM blue LED will pulse to indicate that a BLE connection was established. Then, the reference and calibration data is downloaded from the EVM. When that is completed, the Start Scan button will be activated.

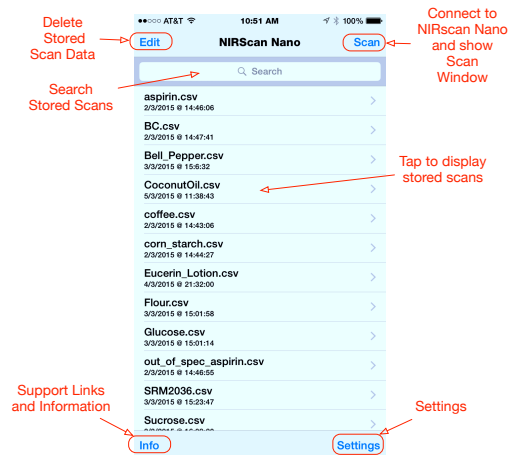


Figure 6-1. NanoScan Main Screen

Pressing the Configure button in the top-right corner of the NanoScan main screen opens the Configuration screen. The Configuration screen displays four buttons:

- Device Information: This button uses the following service:
 - GATT General Information Service to request Manufacture, Model Number, Serial Number, Hardware revision, Tiva firmware version, and Spectrum Library revision.
- Device Status: This button uses the following services:
 - Battery Service to prompt for the Battery voltage. The battery is reported in percentage capacity with 0%, 5%, 20%, 40%, 60%, and 80%.
 - GATT General Information Service to request temperature, humidity, device and error status, and also set threshold for temperature and humidity notifications.
 - GATT General Information Service to report device and error status.
- Scan Configurations: This button uses the following service:
 - GATT Scan Configuration Information Service to display stored scan configurations on the DLP NIRscan Nano. The user can select which stored scan configuration will be used in future scans.

- Stored Scan Data: This button uses the following service:
 - GATT Scan Data Information Service to retrieve stored scan data from the microSD card.

Before starting a scan, the user can set a filename prefix, can elect to also save the scan data on the microSD card, and can choose a default for future scans from the stored scan configurations, as shown in Figure 6-2. Pressing the Start Scan button will start a scan with the selected scan configuration. Once the scan completes, the scan data is transmitted from the NIRScan Nano and plotted. The user can choose to plot absorbance, reflectance, or raw intensity values by tapping on the corresponding button under the plot area.

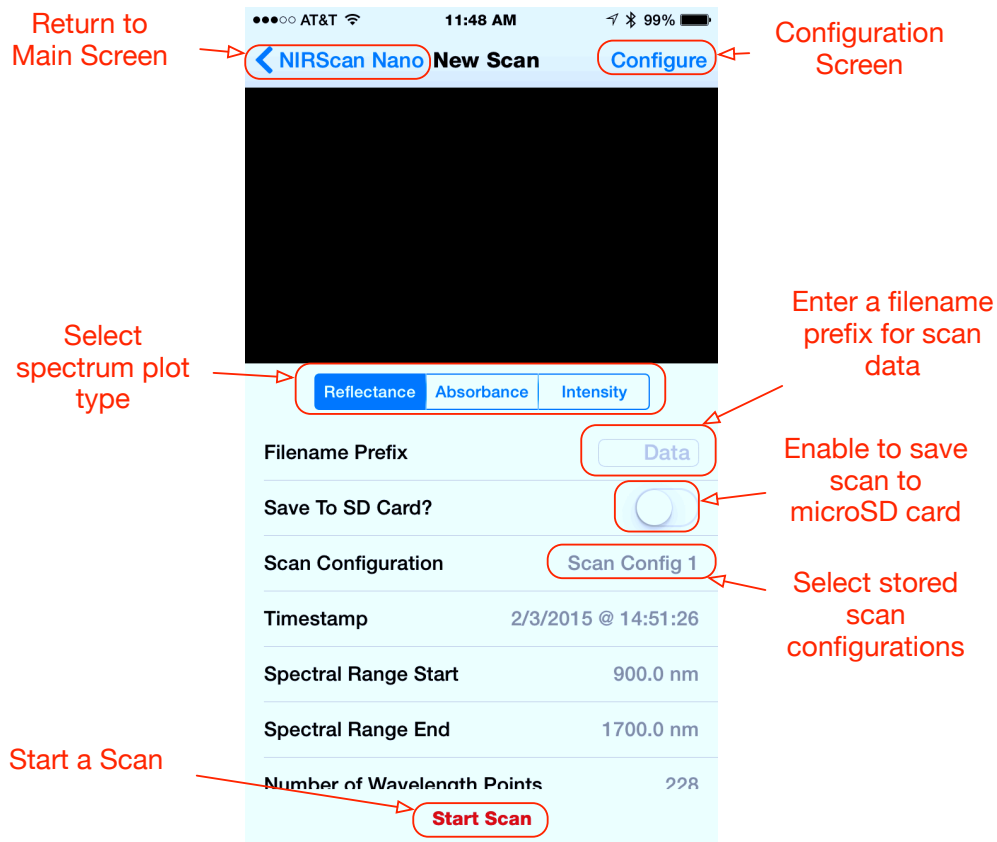


Figure 6-2. NanoScan Scan Screen

Figure 6-3 shows an example plot of absorbance for sugar.

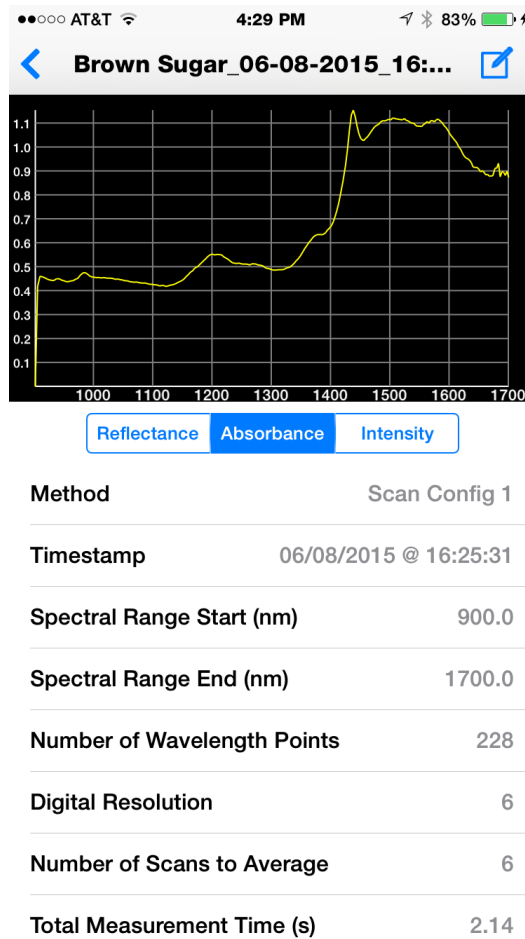


Figure 6-3. NanoScan Scan Plot Screen

Installing the DLP NIRscan Nano Software

A.1 DLP NIRscan Nano Software Installation

The NIRscan Nano software is broken into several packages:

- **DLPNIRscanNanoGUI-1.0.3-windows-installer.exe**
 - This is the PC program that communicates with the DLP NIRscan Nano through USB.
 - This program installs the PC GUI NIRscanNanoGUI.exe under the default directory: C:\Program Files\Texas Instruments\NIRscanNanoGUI_1.0.2\Binaries
 - It also install the sources under the default directory: C:\ti\NIRscanNanoGUI\Sources
- **DLPNIRscanNanoSoftware-windows-installer.exe**
 - This program installs the Tiva binary firmware file under the default directory: C:\ti\DLPNIRscanNanoSoftware_1.0.0\Binaries\NIRscanNano.bin
 - It also installs the sources under the default directory: C:\ti\DLPNIRscanNanoSoftware_1.0.0\Sources
 - This installer includes the TI-RTOS 2.10.1.38 and the Device Firmware Update (DFU) drivers for Tiva. The DFU drivers allow updating the Tiva firmware through USB. If your CCS installation already has TI-RTOS 2.10.1.38, you can skip installing this TI-RTOS package.
- **DLPSpectrumLibrary-1.0.0-windows-installer.exe**
 - This program installs the DLP Spectrum Library. This library code is shared with the PC GUI, Tiva software, and iOS App. The source files are under the default directory: C:\ti\DLPSpectrumLibrary_1.0.0\src.
- **DLPR150PROM-1.0.0-windows-installer.exe**
 - This program installs the DLPC150 firmware binary (DLPR150PROM_1.0.0.img) under the default directory: C:\ti\DLPR150PROM_1.0.0

To install the software, run these installer executables and follow the on-screen prompts.

Required Tools to Compile Tiva Software

B.1 Tiva Tools Installation

To compile the DLP NIRscan Nano Tiva code, the following tools and software packages are required:

- Code Composer Studio (CCS) Integrated Development Environment (IDE) version 6.0.1
- TI-RTOS version 2.10.1.38
- TI ARM Compiler version 5.2.4

B.1.1 Code Composer Studio Installation

To install, follow these steps:

1. Download the latest Windows or Linux version of the [CCS IDE for TM4x ARM MCU](#).
2. Execute the download file: c_setup_win32.exe
3. Accept the License Agreement. Click Next.
4. Select the installation location and click Next. **C:\ti** is the default installation location.
5. If you are running anti-virus software, you will be warned that it is recommended to temporarily disable real-time scanning before proceeding with installation.
6. The installer will prompt for processor support. Ensure that under 32-bit ARM MCUs, Tiva C Series Support and TI ARM Compiler are checked. Click Next.
7. Select the appropriate Debug Probes or Emulators. Tiva C Series are supported by XDS100, XDS200, and XDS560 Debug Probes from TI, Spectrum Digital or Blackhawk.
 - For more information on supported Debug Probes, visit the [Tiva Tools & Software page](#).
 - For emulation information visit the [TI Emulation Wiki](#).
 - For more information on JTAG connectors and adapters visit the [XDS Target Connection Guide](#).
8. If prompted for apps, there is no need to select any apps.
9. After the installation is complete, update CCS by following the steps in [Section B.1.2](#).

B.1.2 Updating TI-RTOS

The current Tiva Firmware build uses TI-RTOS for TivaC 2.10.1.38.

NOTE: Do not use TI-RTOS for TivaC 2.12.1.33 since the TI-RTOS drivers are different.

If you have an older installation of TI-RTOS, update TI-RTOS with the following steps after launching Code Composer Studio:

1. Select CCS APP Center from the View Menu.
2. Type "Tiva" in the search box.
3. Update TI-RTOS for TivaC, if offered to update it. To update it, press the select button beneath the TI-RTOS for TivaC icon and then click on the install software icon to the left of the search box under the App Center logo.

TI-RTOS for TivaC 2.10.1.38 is found at this [link](#).

B.1.2.1 Updating TI ARM Compiler

To update the TI ARM Compiler, follow these steps after launching Code Composer Studio:

1. Select CCS APP Center from the View Menu.
2. Type "compiler" in the search box.
3. Update TI ARM® Compiler, if offered to update it. To update it, press the select button beneath the TI ARM Compiler icon and then click on the install software icon to the left of the search box under the App Center logo.
4. Update TI ARM Compiler for TivaC.

How to Compile Tiva Source Code

C.1 Tiva Libraries Compilation

The DLP NIRscan Nano Tiva software uses two libraries from the TivaWare package: **Tiva driverlib** and **Tiva usblib**. It also uses a third library: **DLP Spectrum Library**. These libraries must be compiled under CCS before building the DLP NIRscan Nano software.

C.1.1 Tiva driverlib Compilation

To compile the TivaWare driverlib library, follow these steps:

1. Import the driverlib library by selecting Import from the File Menu.
2. In the new Import dialog window, select CCS Projects under C/C++ folder and click Next.
3. Find the location of the TivaWare driverlib project by browsing to the directory
C:\ti\tirtos_tivac_2_10_01_38\products\TivaWare_C_Series-2.1.0.12573c\driverlib and click OK.
4. Compile this newly added driverlib project by selecting Clean from the Project Menu. Ensure that driverlib project is checked and select "Build only the selected project" and then click OK.

C.1.2 Tiva usblib Library

To compile the TivaWare usblib library, follow these steps:

1. Import the usblib library by selecting Import from the File Menu.
2. In the new Import dialog window, select CCS Projects under C/C++ folder and click next.
3. Find the location of the TivaWare usblib project by browsing to the directory
C:\ti\tirtos_tivac_2_10_01_38\products\TivaWare_C_Series-2.1.0.12573c\usblib and then click OK.
4. Compile this newly added usblib project by select Clean from the Project Menu. Ensure that usblib project is checked and select "Build only the selected project" and then click OK.

C.1.3 DLP Spectrum Library

The DLP Spectrum Library is a collection of C-language routines that provide the fundamental pieces to use a DLP system in a spectroscopy application. These routines are shared by the Tiva firmware, NIRscan Nano GUI, and iOS App. To compile the DLP Spectrum Library for Tiva firmware, follow these steps:

1. Import the DLP Spectrum Library by selecting Import from the File Menu.
2. In the new Import dialog window, select CCS Projects under C/C++ folder and click Next.
3. Find the location of the dlpspeclib project by browsing to the install directory:
C:\ti\DLPNIRNANO_SPECLIB.
4. Compile this newly added dlpspeclib project by selecting Clean from the Project Menu. Ensure that dlpspeclib project is checked and select "Build only the selected project" and then click OK.

C.2 Tiva Main Source

The Tiva main program sources are installed by the DLPNIRscanNanoSoftware package. This package installs the Code Composer Studio project and source at the default directory
C:\ti\DLPNIRscanNanoSoftware_1.0.0

1. Import the Mobile Spectroscopy Tiva EVM by pulling-down the File Menu and select Import.
2. In the new Import dialog window, select CCS Projects under C/C++ folder and click Next.

3. Find the location of the Mobile Spectroscopy Tiva EVM by browsing to the install directory of the sources: C:\ti\DLPNIRscanNanoSoftware_1.0.0\Sources.
4. Make sure all the other libraries are compiled and imported before this step. Then, compile this newly added Mobile Spectroscopy Tiva EVM project by selecting Clean from the Project Menu. Ensure that dlpspeclib project is checked and select "Build only the selected project" and then click OK.

C.3 Project Settings

The compilation of the Tiva sources and libraries requires the following project settings by right clicking on:

- On Project Browser, select Mobile Spectroscopy Tiva EVM. Right-click and select "Show Build Settings..."
- Under CCS General, select the Main tab. Ensure that the Compiler version is TI v5.2.4.
- Under CCS General, select the RTSC tab. Ensure that TI-RTOS for TivaC is set to 2.10.1.38 and XDCtools version is 3.30.4.52_core.
- Repeat this for all libraries.

Required Tools to Compile NIRscan Nano GUI

D.1 NIRscan Nano GUI

The NIRscan Nano GUI requires Qt Framework and tools 5.4.1 or later, MinGW compiler 4.9.1, and the DLP Spectrum Library. The Qt Framework and tools can be downloaded from the [Qt website](#).

D.1.1 Compiling the DLP Spectrum Library

The DLP Spectrum Library includes a batch file to compile for the PC. To compile the DLP Spectrum Library for the NIRscan Nano GUI, follow these steps:

1. Open MS-DOS window and change to the src directory of the DLP Spectrum Library:
C:/ti/DLPNIRNANO_SPECLIB/src
2. Execute the build-lib.bat file. This batch file requires the prior installation of MinGW or a GCC toolchain in the Windows PC with their respective binaries added to the Windows PATH environment variable.

D.1.2 Compiling NIRscan Nano GUI

After compiling the DLP Spectrum Library, compile the NIRscan Nano GUI with the following steps:

1. Run Qt Creator.
2. In Qt Creator, click on "Open Project" button. Navigate to the directory where the NIRscanNanoGUI sources were installed. The default installation directory is C:\ti\NIRscanNanoGUI\Sources. Open the project file NirscanNanoGUI.pro
3. A dialog window will indicate that no user settings were found. Click the Yes button.
4. Click the Projects icon on the sidebar. Ensure that the Build settings are correct and that an existing Build directory is set.
5. From the Build menu, select Build All.

Tiva EEPROM Contents

E.1 Tiva EEPROM

The Tiva TM4C129XNCZAD microcontroller includes an EEPROM with 6kB of storage. The DLP NIRscan Nano uses this EEPROM to store the following factory information:

- DLP NIRscan Nano Serial Number: A five digit number in the format YMMSSSS, where Y represents a one digit year of manufacturing number, MM represents a two digit month of manufacturing number, and SSSS represents a four digit serial number
- Scan Data Index Counter: Default scan
- Calibration Coefficients Data Structure Version Number
- Calibration Coefficients Data
- Reference Calibration Data Structure Version Number
- Reference Calibration Data
- Default Scan Name
- Default Scan Configuration
- Active Scan Configuration Number and Index
- Scan Configuration Data Structure Version
- Scan Configurations

See [Table E-1](#) for the address, size, and content of these information in Tive EEPROM.

Table E-1. Tiva EEPROM

ADDRESS	SIZE (BYTES)	DESCRIPTION
0x0000	8	DLP NIRscan Nano Serial Number
0x0008	4	Scan Data Session Index
0x000C	4	Scan Configuration Index Counter
0x0010	4	Calibration Coefficients Data Structure Version Number
0x0014	50	Calibration Coefficients Data
0x0046	4	Reference Calibration Data Structure Version Number
0x004A	3632	Reference Calibration Data
0x0E7A	16	Default Scan Name
0x0E7E	4	Active Scan Configuration Number and Index
0x0E82	4	Scan Configuration Data Structure Version
0x0E96	1280	Scan Configurations (64 Scan Configuration entries, with 20 bytes per Scan Configuration)

DLP NIRscan Nano Connectors

F.1 Battery Connector

The battery power (J6) connector of the microprocessor board requires the following 2-pin, 2-mm connector part numbers:

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

The corresponding connector terminal (crimp) part numbers are:

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

Table F-1. Battery Power Connector (Tiva J6)

DESCRIPTION	PIN	SUPPLY RANGE
Power positive	1	4.2 V
Ground	2	Ground

NOTE: The preferred connection to the battery may be a direct solder type or any low resistance contact connection.

F.2 Battery Thermistor Connector

The battery thermistor connector (J7) of the microprocessor board requires the following 2-pin, 1-mm connector part numbers:

- JST part number: SHR-02V-S-B
- Digi-Key part number: 455-1377-ND

The corresponding connector terminal (crimp) part numbers are:

- JST part number: SSH-003T-P0.2
- Digi-Key part number: 455-1561-1-ND

Table F-2. Battery Thermistor Connector (Tiva J7)

DESCRIPTION	PIN	SUPPLY RANGE
Power positive	1	4.9 V
Ground	2	Ground

F.3 Expansion Connector

The expansion connector (J3) of the microprocessor board requires the following 10-pin, 1-mm connector part numbers:

- JST part number: SHR-10V-S-B
- Digi-Key part number: 455-1385-ND

The corresponding connector terminal (crimp) part numbers are:

- JST part number: SSH-003T-P0.2
- Digi-Key part number: 455-1561-1-ND

Table F-3. Expansion Connector (Tiva J3)

DESCRIPTION	PIN	SUPPLY RANGE
Power	1	3.3 V
Ground	2	Ground
Tiva PA2 (GPIO, UART4 receive or SSI0 clock)	3	3.3 V
Tiva PA3 (GPIO, UART4 transmit or SSI0 frame sync)	4	3.3 V
Tiva PA4 (GPIO or SSI0 Data0)	5	3.3 V
Tiva PA5 (GPIO or SSI0 Data1)	6	3.3 V
Tiva PK2 (GPIO or UART4RTS)	7	3.3 V
Tiva PK3 (GPIO or UART4 CTS)	8	3.3 V
Ground	9	Ground
Tiva wake	10	3.3 V

F.4 JTAG Connector

The ARM Cortex 10-pin JTAG connector (J4) of the Microprocessor Board requires an adapter to interface to the standard TI 14-pin and 20-pin emulators. Refer to the [TI JTAG Connector wiki page](#) for more information.

Table F-4. ARM Cortex 10-pin JTAG Connector (Tiva J4)

DESCRIPTION	PIN	SUPPLY RANGE
Power	1	3.3 V
TMS	2	3.3 V
Ground	3	Ground
TCK	4	3.3 V
Ground	5	Ground
TDO	6	3.3 V
Key (no connect)	7	—
TDI	8	3.3 V
Ground	9	Ground
RESETz	10	3.3 V

F.5 Trigger Connector

The trigger connector (J500) of the DLPC150 board requires the following 9-pin, 1-mm connector part numbers:

- JST part number: SHR-09V-S-B
- Digi-Key part number: SHR-09V-S-B

The corresponding connector terminal (crimp) part numbers are:

- JST part number: SSH-003T-P0.2
- Digi-Key part number: 455-1561-1-ND

Note that this connector is on the top side of the DLPC150 board covered by the plastic cover. To access this connector, the microprocessor and DLPC150 boards must be disassembled from the optical module. Do not remove the top cover because it protects the optical module from dust and keeps the lenses in place.

Table F-5. Trigger Connector (DLPC150 J500)

DESCRIPTION	PIN	SUPPLY RANGE
Tiva PD2 (lamp control)	1	3.3 V
TRIG_IN_1	2	3.3 V
Ground	3	Ground
DLPC150 GPIO_17	4	3.3 V
DLPC150 GPIO_18	5	3.3 V
Ground	6	Ground
TRIG_OUT_2 (frame trigger)	7	3.3 V
TRIG_OUT_1 (pattern trigger)	8	3.3 V
Ground	9	Ground

DLP NIRscan Nano Command Description

G.1 Command Handler Supported Commands

The DLP NIRscan Nano Command Handler supports a set of commands described in [Table G-1](#).

Table G-1. DLP NIRscan Nano Supported Commands

READ / WRITE	DESCRIPTION	COMMUNICATIONS INTERFACE				
		USB		BLUETOOTH		
		OPCODE		SERVICE NAME	SERVICE UUID	CHARACTERISTIC UUID
		BYTE 1	BYTE 2			
READ	Perform file checksum	0x00	0x15			
WRITE	Write file data	0x00	0x25			
WRITE	Write file size	0x00	0x2C			
READ	Read file size	0x00	0x2D			
READ	Read file data	0x00	0x2E			
WRITE	Update Tiva firmware	0x00	0x2F			
READ	EEPROM test	0x01	0x01			
READ	Detector board test	0x01	0x02			
READ	Battery charger test	0x01	0x03			
READ	SDRAM test	0x01	0x04			
WRITE	DLP Controller power up test	0x01	0x05			
READ	Temperature sensor test	0x01	0x06			
READ	Humidity sensor test	0x01	0x07			
WRITE	Bluetooth test	0x01	0x08			
READ	microSD Card test	0x01	0x09			
READ	LED test	0x01	0x0B			
READ	Read button test	0x01	0x0C			
WRITE	Write button test	0x01	0x0D			
WRITE	FACTORY USE ONLY: Write EEPROM Calibration Coefficient, Scan Configuration, and Reference Calibration Coefficients Versions ⁽¹⁾	0x01	0x0E			
READ	Read version information	0x02	0x16	Device Information Service Table I-1	0x180A	0x2829, 0x2A24, 0x2A26, 0x2A27, 0x2A28
WRITE	Write patterns in SDRAM	0x02	0x17			
WRITE	Start scan	0x02	0x18	GATT Scan Data Information Service Table I-7	0x53455206-444C-5020-4E49-52204E616E6F	0x4348411D-444C-5020-4E49-52204E616E6F

⁽¹⁾ Commands highlighted in red are for factory calibration. Erasing the factory calibration data will render a unit non-functional and will need to be recalibrated.

Table G-1. DLP NIRscan Nano Supported Commands (continued)

READ / WRITE	DESCRIPTION	COMMUNICATIONS INTERFACE				
		USB		BLUETOOTH		
		OPCODE		SERVICE NAME	SERVICE UUID	CHARACTERISTIC UUID
		BYTE 1	BYTE 2			
READ	Scan status	0x02	0x19	GATT General Information Service Table I-3	0x53455201-44C-5020-4E49-52204E616E6F	0x43484103-444C-5020-4E49-52204E616E6F, 0x43484104-444C-5020-4E49-52204E616E6F
WRITE	Reset Tiva	0x02	0x1A			
WRITE	Write ADC PGA gain	0x02	0x1B			
WRITE	FACTORY USE ONLY: Write DLPC150 Register ⁽¹⁾	0x02	0x1C			
READ	Read DLPC150 register	0x02	0x1D			
WRITE	Generate patterns	0x02	0x1E			
WRITE	Save given scan configuration in EEPROM	0x02	0x1F			
READ	Read stored scan configurations	0x02	0x20	GATT Scan Configuration Information Service Table I-6	0x53455205-44C-5020-4E49-52204E616E6F	0x43484114-444C-5020-4E49-52204E616E6F, 0x43484115-444C-5020-4E49-52204E616E6F, 0x43484116-444C-5020-4E49-52204E616E6F
WRITE	Erase all stored scan configurations	0x02	0x21			
READ	Read number of stored scan configurations	0x02	0x22	GATT Scan Configuration Information Service Table I-6	0x53455205-44C-5020-4E49-52204E616E6F	0x43484113-444C-5020-4E49-52204E616E6F
READ	Read active scan configuration	0x02	0x23			0x43484117-444C-5020-4E49-52204E616E6F
WRITE	Set active scan configuration	0x02	0x24			0x43484118-444C-5020-4E49-52204E616E6F
WRITE	DLPC150 power control	0x02	0x25			
WRITE	Set scan subimage	0x02	0x26			
WRITE	FACTORY USE ONLY: Erase Calibration Coefficients, Reference Calibration Coefficients, and Scan Configuration stored in EEPROM ⁽²⁾	0x02	0x27			
READ	Read PGA setting	0x02	0x28			
WRITE	FACTORY USE ONLY: Write spectrum calibration coefficients ⁽²⁾	0x02	0x29			

⁽²⁾ Commands highlighted in red are for factory calibration. Erasing the factory calibration data will render a unit non-functional and will need to be recalibrated.

Table G-1. DLP NIRscan Nano Supported Commands (continued)

READ / WRITE	DESCRIPTION	COMMUNICATIONS INTERFACE				
		USB		BLUETOOTH		
		OPCODE		SERVICE NAME	SERVICE UUID	CHARACTERISTIC UUID
		BYTE 1	BYTE 2			
READ	Read spectrum calibration coefficients	0x02	0x2A	GATT Calibration Information Service Table I-5	0x53455204-44C-5020-4E49-52204E616E6F	0x4348410D-444C-5020-4E49-52204E616E6F, 0x4348412E-444C-5020-4E49-52204E616E6F, 0x4348410F-444C-5020-4E49-52204E616E6F, 0x43484110-444C-5020-4E49-52204E616E6F, 0x43484111-444C-5020-4E49-52204E616E6F, 0x43484112-444C-5020-4E49-52204E616E6F
WRITE	Compute SNR	0x02	0x2B			
READ	Read SNR calculation results	0x02	0x2C			
WRITE	Generate calibration pattern	0x02	0x2D			
WRITE	Write number of scan repeats	0x02	0x2E			
WRITE	FACTORY USE ONLY: Reference Calibration in EEPROM ⁽²⁾	0x02	0x30			
WRITE	FACTORY USE ONLY: Write Device Serial Number ⁽²⁾	0x02	0x32			
READ	Read device serial number	0x02	0x33	Device Information Service Table I-1	0x180A	0x2A25
WRITE	Set scan name tag	0x02	0x34	GATT Scan Data Information Service Table I-7	0x53455206-44C-5020-4E49-52204E616E6F	0x4348411C-444C-5020-4E49-52204E616E6F
WRITE	Erase specified scan from microSD card	0x02	0x35			0x4348411E-444C-5020-4E49-52204E616E6F
WRITE	FACTORY USE ONLY: Mass erase Tiva EEPROM ⁽²⁾	0x02	0x36			
READ	Read temperature (TMP006) sensor	0x03	0x00	GATT General Information Service Table I-3	0x53455201-44C-5020-4E49-52204E616E6F	0x43484101-444C-5020-4E49-52204E616E6F
WRITE	Set temperature threshold					0x43484105-444C-5020-4E49-52204E616E6F
READ	Read humidity (HDC1000) sensor	0x03	0x02			0x43484102-444C-5020-4E49-52204E616E6F
WRITE	Set humidity threshold					0x43484106-444C-5020-4E49-52204E616E6F
WRITE	Set time and date	0x03	0x09	GATT Date and Time Service Table I-4	0x53455203-44C-5020-4E49-52204E616E6F	0x4348410C-444C-5020-4E49-52204E616E6F
READ	Read battery voltage	0x03	0x0A	Battery Service Table I-2	0x180F	0x2A19
READ	Read Tiva internal temperature	0x03	0x0B			

Table G-1. DLP NIRscan Nano Supported Commands (continued)

READ / WRITE	DESCRIPTION	COMMUNICATIONS INTERFACE				
		USB		BLUETOOTH		
		OPCODE		SERVICE NAME	SERVICE UUID	CHARACTERISTI C UUID
		BYTE 1	BYTE 2			
READ	Get time and date	0x03	0x0C	GATT Date and Time Service Table I-4	0x53455203-444C- 5020-4E49- 52204E616E6F	0x4348410C-444C- 5020-4E49- 52204E616E6F
WRITE	Set Tiva in hibernation mode	0x03	0x0D			
READ	Read number of scan files stored in microSD card	0x04	0x00	GATT Scan Data Information Service Table I-7	0x53455206-444C- 5020-4E49- 52204E616E6F	0x43484119-444C- 5020-4E49- 52204E616E6F, 0x4348411A-444C- 5020-4E49- 52204E616E6F, 0x4348411B-444C- 5020-4E49- 52204E616E6F
READ	Read Photodetector	0x04	0x02			

DLP NIRscan Nano USB Communications

USB Communications

The DLP NIRscan Nano communicates using USB 1.1 human interface device (HID) to exchange commands and data with a host processor or PC. The USB commands are variable length data packets that are sent with the least significant byte first. The maximum HID packet length is 64 bytes.

The DLP NIRscan Nano enumerates as a Texas Instruments HID device with vendor ID = 0x0451 and product ID = 0x4200.

USB Transaction Sequence

The USB 1.1 HID protocol has the structure shown in [Figure H-1](#):

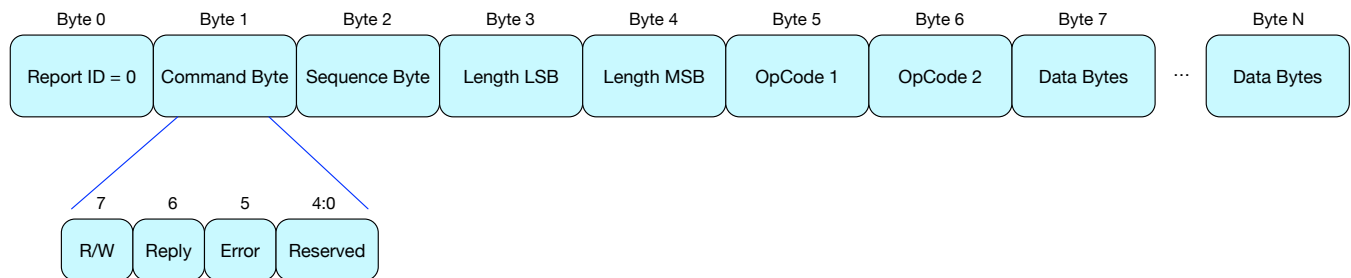


Figure H-1. USB HID Protocol

H.0.0.1 USB Read Transaction Sequence

To issue a read command, the host must perform the following steps:

1. Host sends the Report ID byte, which is set to 0.
2. Host sends the Command ID byte, where:
 - Bit 6 is set to 0x1 to indicate the host wants a reply from the device.
 - Bit 7 is set to 0x1 to indicate a read transaction.
3. Host sends the Sequence byte. When a single command is more than 64 bytes, it is sent as multiple USB packets and the sequence byte is used to number the packets so the device can assemble them in the right sequence. Otherwise, this value is irrelevant and generally set to 0.
4. Host sends two bytes with the length of the data packet. This length denotes the number of data bytes in the packet and excludes the number of bytes in steps 1 through 4. It denotes the total number of bytes sent in steps 5 (command bytes) and 6 (data bytes).
5. Host sends two OpCode bytes: OpCode Byte 1 and OpCode Byte 2.
6. Host sends data appropriate to command.
7. After completion of this command, DLP NIRscan Nano responds with a packet that includes:
 - (a) Byte with the command requested by the host (the matching Sequence byte)
 - (b) Length of the data packet
 - (c) Data requested

H.0.0.2 USB Write Transaction Sequence

To issue a write command, the host must perform the following steps:

1. Host sends the Report ID byte, which is set to 0.
2. Host sends the Flags byte, where
 - Bit 6 is set to 0x1 to indicate the host wants a reply from the device. The device responds with the NACK bit set if an unknown command was received or there was any error in processing the command due to invalid parameters or other reasons..
 - Bit 7 is set to 0x1 to indicate a read transaction
3. Host sends the Sequence byte. When a single command is more than 64 bytes, it is sent as multiple USB packets and the sequence byte is used to number the packets so the device can assemble them in the right sequence. In other cases, this value is irrelevant and generally set to 0.
4. Host sends two bytes with the length of the data packet. This length denotes the number of data bytes in the packet and excludes the number of bytes in steps 1 through 4. It denotes the total number of bytes sent in steps 5 (command bytes) and 6 (data bytes).
5. Host sends three OpCode bytes: OpCode Byte 1 and OpCode Byte 2.
6. Host sends data appropriate to command.
7. After completion of this command, DLP NIRscan Nano responds with a packet that includes a byte with the command requested by the host. This occurs only if bit 6 was set in the Flags byte.

DLP NIRscan Nano Bluetooth Communications

I.1 Bluetooth Communications

The DLP NIRscan Nano wirelessly communicates using Bluetooth Low Energy version 4.0. This wireless communication uses two main profiles for discovery and communication with a remote host:

- GAP: Generic access profile for basic discovery and establishing connections.
- GATT: Generic attribute profile for commands and data transfer.

The DLP NIRscan Nano supports Bluetooth version 4.0 specification. When the Bluetooth sub-system is activated, the DLP NIRscan Nano broadcasts its availability while a smartphone, tablet or PC acts as an observer. Once connected, the DLP NIRscan Nano acts as a server for the GATT profile while the smartphone, tablet, or PC acts as a client.

I.1.1 GATT Supported Services

The DLP NIRscan Nano Bluetooth GATT Profile supports the following services:

- Battery Service (BAS) to provide battery charge capacity.
- Device Information Service (DIS) to provide manufacturer Name, model number, serial number, hardware revision, spectrum library revision, and Tiva software revision.
- GATT General Information Service to provide temperature, humidity, status, hours of use, lamp hours, and battery recharge cycles.
- GATT Date and Time Service to synchronize date and time information between smartphone, tablet, or PC to the Tiva's realtime clock.
- GATT Calibration Information Service to provide calibration coefficients
- **GATT Scan Configuration Information Service** to provide stored configurations and scan configuration data.
- **GATT Scan Data Information Service** to initiate scan, clear scan data, and return stored scan data.

A GATT service has a universally unique identifier (UUID) used to identify every service. A UUID is a 128-bit value. However, common or frequently used services that are included in the BLE specifications and/or certified by Bluetooth.org are shortened to 16-bit UUID to improve efficiency.

Each service is composed of a set of characteristics. Each characteristic contains a value with properties for how the value is accessed and information on how the value is displayed or represented. The properties are:

- **R = Read.**
- **W = Write.**
- **WwR = Write without response.** Not used in DLP NIRscan Nano Bluetooth implementation.
- **S = Signed write.** Not used in DLP NIRscan Nano Bluetooth implementation.
- **N = Notify.**
- **I = Indicate.**
- **WA = Writable auxiliaries.** Not used in DLP NIRscan Nano Bluetooth implementation.
- **B = Broadcast.** Not used in DLP NIRscan Nano Bluetooth implementation.
- **EP = Extended properties.** Not used in DLP NIRscan Nano Bluetooth implementation.

An "X" in a supported property indicates the properties supported by a characteristic. Empty columns indicate properties not supported by the characteristic.

A data size entry with an MP value represents multiple packets. All data is transmitted little-endian.

Table I-1. Device Information Service (DIS)

SERVICE UUID	DESCRIPTION							
0x180A	DEVICE INFORMATION SERVICE (DIS)							
CHARACTERIS TIC UUID	DESCRIPTION	DATA FORMAT	DATA SIZE (BYTES)	SUPPORTED PROPERTIES				NOTES
				R	W	N	I	
0x2829	Manufacturer name string	string	1	X				org.bluetooth.characteristic.manufacturer_name_string
0x2A24	Model number string	string	1	X				org.bluetooth.characteristic.model_number_string
0x2A25	Serial number string	string	1	X				org.bluetooth.characteristic.serial_number_string
0x2A27	Hardware revision string	string	1	X				org.bluetooth.characteristic.hardware_revision_string
0x2A26	Tiva firmware revision string	string	1	X				org.bluetooth.characteristic.firmware_revision_string
0x2A28	Spectrum library revision string	unsigned integer	2	X				org.bluetooth.characteristic.software_revision_string

Table I-2. Battery Service (BAS)

SERVICE UUID	DESCRIPTION							
0x180F	BATTERY SERVICE (BAS)							
CHARACTERIS TIC UUID	DESCRIPTION	DATA FORMAT	DATA SIZE (BYTES)	SUPPORTED PROPERTIES				NOTES
				R	W	N	I	
0x2A19	Battery level	unsigned integer	1	X				org.bluetooth.service.battery_service . Value reported in the range of 0-100.

Table I-3. GATT General Information Service

SERVICE UUID	DESCRIPTION							
0x53455201-444C-5020-4E49-52204E616E6F	GATT GENERAL INFORMATION SERVICE							
CHARACTERISTIC UUID	DESCRIPTION	DATA FORMAT	DATA SIZE (BYTES)	SUPPORTED PROPERTIES				NOTES
				R	W	N	I	
0x43484101-444C-5020-4E49-52204E616E6F	Temperature measurement	integer	2	X		X		Integer value returned in hundredths. Divide by 100 to get the actual floating point number.
0x43484102-444C-5020-4E49-52204E616E6F	Humidity measurement	unsigned integer	2	X		X		
0x43484103-444C-5020-4E49-52204E616E6F	Device status (Reserved for future support)	unsigned integer	2	X		X		
0x43484104-444C-5020-4E49-52204E616E6F	Error status (Reserved for future support)	unsigned integer	2	X		X		
0x43484105-444C-5020-4E49-52204E616E6F	Temperature threshold	integer	2		X			Value set in hundredths. Input truncated integer of actual value multiplied by 100.
0x43484106-444C-5020-4E49-52204E616E6F	Humidity threshold	unsigned integer	2		X			
0x43484107-444C-5020-4E49-52204E616E6F	Number of hours of use (Reserved for future support)	unsigned integer	2	X				
0x43484108-444C-5020-4E49-52204E616E6F	Number of battery recharge cycles (Reserved for future support)	unsigned integer	2	X				
0x43484109-444C-5020-4E49-52204E616E6F	Total lamp hours (Reserved for future support)	unsigned integer	2	X				
0x4348410A-444C-5020-4E49-52204E616E6F	Error log (Reserved for future support)	string	1	X				

Table I-4. GATT Date and Time Service

SERVICE UUID	DESCRIPTION						
0x53455203-444C-5020-4E49-52204E616E6F	GATT CURRENT DATE AND TIME						
CHARACTERISTIC UUID	DESCRIPTION	DATA FORMAT	DATA SIZE (BYTES)	SUPPORTED PROPERTIES			
				R	W	N	I
0x4348410C-444C-5020-4E49-52204E616E6F	Current year (0-99: starting in year 2000)	unsigned integer	1		X		
	Current month (1-12)	unsigned integer	1				
	Current day (1-31)	unsigned integer	1				
	Current day of the week (0-6)	unsigned integer	1				
	Current hour (0-23)	unsigned integer	1				
	Current minute (0-59)	unsigned integer	1				
	Current second (0-59)	unsigned integer	1				

Table I-5. GATT Calibration Information Service

SERVICE UUID	DESCRIPTION							
0x53455204-444C-5020-4E49-52204E616E6F	GATT CALIBRATION INFORMATION SERVICE							
CHARACTERISTIC UUID	DESCRIPTION	DATA FORMAT	DATA SIZE (BYTES)	SUPPORTED PROPERTIES				NOTES
				R	W	N	I	
0x4348410D-444C-5020-4E49-52204E616E6F	Request Spectrum Calibration Coefficients	unsigned integer	1		X			Indicate intent to read. No data transferred.
0x4348412E-444C-5020-4E49-52204E616E6F	Return Spectrum Calibration Coefficients		MP			X		Send 6 coefficients. Each coefficient is a double data-type of 8 bytes. The data is sent in serialized manner.
0x4348410F-444C-5020-4E49-52204E616E6F	Request Reference Calibration Coefficients	unsigned integer	1		X			Indicate intent to read. No data transferred.
0x43484110-444C-5020-4E49-52204E616E6F	Return Reference Calibration Coefficients		MP			X		Serialized data; refer to spectrum C library for data structure.
0x43484111-444C-5020-4E49-52204E616E6F	Request Reference Calibration Matrix	unsigned integer	1		X			Indicate intent to read. No data transferred.
0x43484112-444C-5020-4E49-52204E616E6F	Return Reference Calibration Matrix		MP			X		Serialized data; refer to spectrum C library for data structure.

Table I-6. GATT Scan Configuration Information Service

SERVICE UUID	DESCRIPTION							
0x53455205-444C-5020-4E49-52204E616E6F	GATT SCAN CONFIGURATION INFORMATION SERVICE							
CHARACTERISTIC UUID	DESCRIPTION	DATA FORMAT	DATA SIZE (BYTES)	SUPPORTED PROPERTIES				NOTES
				R	W	N	I	
0x43484113-444C-5020-4E49-52204E616E6F	Number of stored configurations	unsigned integer	2	X				
0x43484114-444C-5020-4E49-52204E616E6F	Request stored configurations list	unsigned integer	1		X			No data transmitted.
0x43484115-444C-5020-4E49-52204E616E6F	Return stored configurations list		MP			X		List of 2 byte indices.
0x43484116-444C-5020-4E49-52204E616E6F	Request scan configuration data	unsigned integer	2		X			Index to read.
0x43484117-444C-5020-4E49-52204E616E6F	Return scan configuration data		MP			X		Serialized data; refer to spectrum C library for data structure.
0x43484118-444C-5020-4E49-52204E616E6F	Active scan configuration		2	X	X			Get/Set function. Parameter transmitted is a 2-byte index.

Table I-7. GATT Scan Data Information Service

SERVICE UUID	DESCRIPTION							
0x53455206-444C-5020-4E49-52204E616E6F	GATT SCAN DATA INFORMATION SERVICE							
CHARACTERISTIC UUID	DESCRIPTION	DATA FORMAT	DATA SIZE (BYTES)	SUPPORTED PROPERTIES				NOTES
				R	W	N	I	
0x43484119-444C-5020-4E49-52204E616E6F	Number of stored scans	unsigned integer	4	X				
0x4348411A-444C-5020-4E49-52204E616E6F	Stored scan indices list	unsigned integer	4		X			No data transmitted.
0x4348411B-444C-5020-4E49-52204E616E6F	Stored scan indices list		MP			X		Multiple packet transfer of five 4-byte indices per packet.
0x4348411C-444C-5020-4E49-52204E616E6F	Set scan name stub	string	2		X			Limited to 15 bytes.

Table I-7. GATT Scan Data Information Service (continued)

SERVICE UUID	DESCRIPTION							
0x53455206-444C-5020-4E49-52204E616E6F	GATT SCAN DATA INFORMATION SERVICE							
CHARACTERISTIC UUID	DESCRIPTION	DATA FORMAT	DATA SIZE (BYTES)	SUPPORTED PROPERTIES				NOTES
				R	W	N	I	
0x4348411D-444C-5020-4E49-52204E616E6F	Start scan	unsigned integer	1		X	X		Parameter value: 0x00 = do not store scan in microSD card 0x01 = store scan in microSD card. Notification returned: 0xFF = scan completed
0x4348411E-444C-5020-4E49-52204E616E6F	Clear scan	unsigned integer	4		X	X		Index of scan data to clear. Notification returned: 0x00 = success non-zero return is an error
0x4348411F-444C-5020-4E49-52204E616E6F	Request scan name	unsigned integer	4		X			Index of scan data to read.
0x43484120-444C-5020-4E49-52204E616E6F	Return scan name	string	20			X		Scan name limited to 20 characters.
0x43484121-444C-5020-4E49-52204E616E6F	Request scan type	unsigned integer	4		X			Index of scan data to read.
0x43484122-444C-5020-4E49-52204E616E6F	Return scan type	unsigned integer	1			X		
0x43484123-444C-5020-4E49-52204E616E6F	Request scan date/time	unsigned integer	4		X			
0x43484124-444C-5020-4E49-52204E616E6F	Return scan date/time	unsigned integer	7			X		Seven bytes returned. Same format as GATT Date and Time Service.
0x43484125-444C-5020-4E49-52204E616E6F	Request packet format version	unsigned integer	4		X			Index of data to read.
0x43484126-444C-5020-4E49-52204E616E6F	Return packet format version	unsigned integer	4			X		

Table I-7. GATT Scan Data Information Service (continued)

SERVICE UUID	DESCRIPTION							
0x53455206-444C-5020-4E49-52204E616E6F	GATT SCAN DATA INFORMATION SERVICE							
CHARACTERISTIC UUID	DESCRIPTION	DATA FORMAT	DATA SIZE (BYTES)	SUPPORTED PROPERTIES				NOTES
				R	W	N	I	
0x43484127-444C-5020-4E49-52204E616E6F	Request serialized scan data structure	unsigned integer	4		X			Index of data to read
0x43484128-444C-5020-4E49-52204E616E6F	Return serialized scan data structure		MP			X		Serialized data; refer to spectrum C library for data structure.

I.2 Bluetooth Packets

Bluetooth transmits in short packet sizes. The typical maximum transmission unit for an iOS App is 20 bytes. Multiple packets are needed to transfer the following information to DLP NIRscan Nano:

- Spectrum Calibration Coefficients
- Reference Calibration Coefficients
- Stored Configurations List
- Scan Configuration Data
- Stored Scan Indices
- Serialized Scan Data Structure

The previous tables label the data size as MP to denote that multiple packets are used during transfer. The packet structure is:

- First Packet:
 - Packet Index: 00 (one byte)
 - Data size in bytes (4 bytes)
- Nth Packet:
 - Packet Index: N-1 (one byte describing the current packet number, zero-based)
 - Data Packet: data (up to 19 bytes)

Revision B History

Changes from A Revision (June 2015) to B Revision	Page
• Updated locations of firmware files in Section 3.1.4	29
• Deleted OpCode Byte 3.....	58
• Added USB Communications HID packet description	62

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

Revision A History

Changes from Original (June 2015) to A Revision	Page
• Added missing thermistor from block diagram and moved red LED to bq24250	9
• Changed description to include more information	12
• Changed list of DLLs	18
• Changed description of scan configuration parameters	22
• Changed battery requirements.....	31
• Changed DLP Spectrum Library description	37
• Added DLP Spectrum Library workflow diagrams	37
• Changed semaphore location to be outside of tasks	40
• Added Bluetooth Client App Workflow	40
• Changed software version numbers	48
• Added steps to compile NIRscanNanoGUI and its DLP Spectrum Library under Windows	53
• Changed Command Handler Table to show the exact USB commands and Bluetooth services.....	58
• Added notes to the GATT services characteristics.....	65

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

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