Ocean Optics

A HALMA GROUP COMPANY

USB2000+ Data Sheet

Description

The Ocean Optics USB2000+ Spectrometer includes the linear CCD-array optical bench, plus all the circuits necessary for spectrometer operation. The result is a compact, flexible system, with no moving parts, that's easily integrated as an OEM component.

The USB2000+ spectrometer is a unique combination of technologies providing users with both an unusually high spectral response and high optical resolution in a single package. The electronics have been designed for considerable flexibility in connecting to various modules as well as external interfaces. The USB2000+ interfaces to PCs, PLCs and other embedded controllers through USB 2.0 or RS-232 communications. The information included in this guide provides detailed instructions on the connection and operation of the USB2000+.

The detector used in the USB2000+ spectrometer is a high-sensitivity 2048-element CCD array from Sony, product number ILX511. (For complete details on this detector, visit Sony's web site at www.sony.com. Ocean Optics applies a coating to all ILX511 detectors, so the optical sensitivity could vary from that specified in the Sony datasheet).

The USB2000+ operates off of a single +5VDC supply and either a USB or RS-232 interface. The USB2000+ is a microcontroller-controlled spectrometer, thus all operating parameters are implemented through software interfacing to the unit.

A special 500 lines/mm groove density grating option used in the USB2000+XR spectrometer provides broader spectral coverage with no sacrifice in performance. This extended-range spectrometer is preconfigured with this new grating for general-purpose UV-NIR applications.

Features

- ILX511 Detector
  - High sensitivity detector
  - Readout Rate: 2.4MHz
- Optics
  - An optical resolution of ~0.1nm (FWHM)
  - A wide variety of optics available
    - 14 gratings, plus Grating #31for the XR version
    - 6 slit widths
    - 3 detector coatings
    - 6 optical filters
- Electrical Performance
  - 16 bit, 3MHz A/D Converter
  - Integration times from 1ms to 65s
- 4 triggering modes
- Embedded microcontroller allows programmatic control of all operating parameters & Standalone operation
  - USB 2.0 480Mbps (High Speed) & 12Mbps (Full speed)
  - RS232 115Kbaud
  - Multiple Communication Standards for digital accessories (SPI, I^2C)
- Onboard Pulse Generator
  - 2 programmable strobe signals for triggering other devices
  - Software control of nearly all pulse parameters
- Onboard GPIO
  - 8 user programmable digital I/O
- EEPROM storage for
  - Wavelength Calibration Coefficients
  - Linearity Correction Coefficients
  - Absolute Irradiance Calibration (optional)
- Plug-n-Play Interface for PC applications
- 22-pin connector for interfacing to external products
- CE Certification

Specifications

Specifications	Criteria

Absolute Maximum Ratings:
  V_{CC}
  Voltage on any pin
	
	+ 5.5 VDC
	+4VDC

Physical Specifications:
  Physical Dimensions
  Weight
	
	89.1 mm x 63.3 mm x 34.4 mm
	190 g

Power:
  Power requirement (master)
  Supply voltage
  Power-up time
	
	250 mA at +5 VDC
	4.5 – 5.5 V
	~2s depending on code size

Spectrometer:
  Design
  Focal length (input)
  Focal length (output)
  Input Fiber Connector
  Gratings
  Entrance Slit
 	
  Detector
  Filters
	
	Asymmetric crossed Czerny-Turner
	42mm
	68mm (75, 83, and 90mm focal lengths are also available)
	SMA 905
	14 different gratings, plus Grating #31 for the XR version
	5, 10, 25, 50, 100, or 200 µm slits. (Slits are optional. In the absence of a slit, the fiber acts as the entrance slit.)
	Sony ILX511B CCD
	2nd and 3rd order rejection, long pass (optional)

Spectroscopic:
  Integration Time
  Dynamic Range
  Signal-to-Noise
  Readout Noise (single dark spectrum)
  Resolution (FWHM)
 	
  Stray Light
  Spectrometer Channels
	
	1 ms – 65 sec
	2×10^{8}(system), 1300:1 (single acquisition)
	250:1 single acquisition
	50 counts RMS, 300 counts peak-to-peak
	0.1 – 10.0 nm varies by configuration (see www.Oceanoptics.com for configuration options)
	<0.05% at 600 nm; <0.10% at 435 nm
	One

Environmental Conditions:
  Temperature
  Humidity
	
	-30° to +70° C Storage & -10° to +50° C Operation
	0% - 90% noncondensing

Interfaces:
  USB
  RS-232
	
	USB 2.0, 480 Mbps
	2-wire RS-232

Mechanical Diagrams

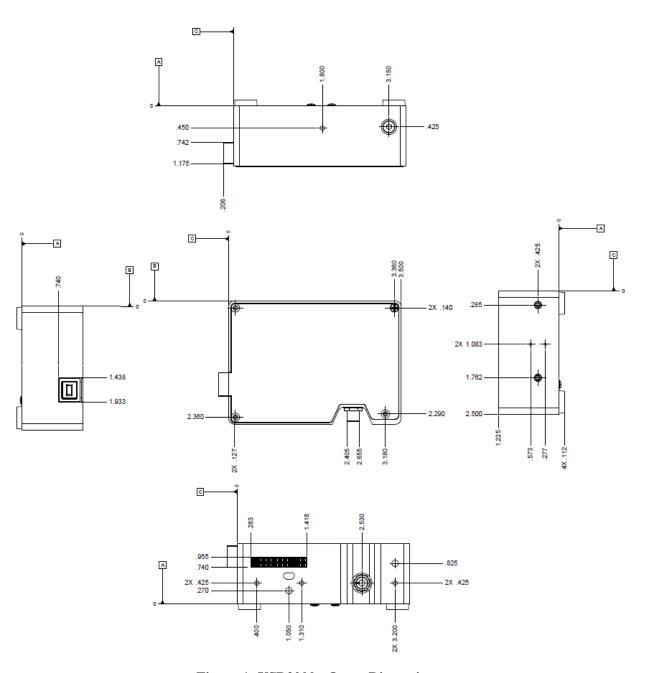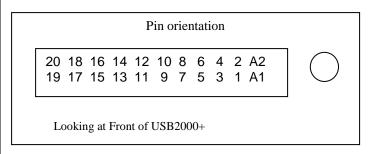**Figure 1: USB2000+ Outer Dimensions**

Electrical Pinout

Listed below is the pin description for the USB2000+ Accessory Connector located on the front vertical wall of the unit. The connector is a Samtec part # IPT1-111-01-S-D-RA connector. The vertical mate to this is part #IPS1-111-01-S-D-VS and the right angle PCB mount is part #IPS1-111-01-S-D-RA.

Pin#	Description	Alt Function
A1	SPI_CLK	
A2	SPICS_OUT	
1	VUSB	
2	Tx	
3	Rx	
4	LampEnable	
5	ContStrobe	
6	GND	
7	ExtTrigIn	
8	Single Strobe	
9	SCL	
10	SDA	
11	MOSI	
12	MISO	
13	GPIO-1 (1P)*	Master Clock
14	GPIO-0 (2P)	Base Clock
15	GPIO-3 (1N)	Integration Clock
16	GPIO-2 (2N)	Reserved
17	GPIO-5 (3P)	Acquire Spectra (Read Enable)
18	GPIO-4 (4P)	Reserved
19	GPIO-7 (3N)	SH CCD pin
20	GPIO-6 (4N)	ICG CCD pin

Pin orientation

```
20  18  16  14  12  10  8   6   4   2  A2        ◯
19  17  15  13  11  9   7   5   3   1  A1
```

Looking at Front of USB2000+

Notes:

- GPIO nP & nN notation is for future LVDS capability
- 5V Aux pin on the GPIO header is output only

Function	Input/Output	Description
V_{CC} , V_{USB} or $5V_{in}$	Input or Output	This is the input power pin to the USB2000+. Additionally when operating via a Universal Serial Bus (USB) this is the USB power connection (+5V) which can be used to power other peripherals (Care must be taken to insure that the peripheral complies with USB Specifications). NOTE: Do not connect both USB power and Auxiliary power (as an input) at the same time.
RS232 Tx	Output	RS232 Transmit signal – for communication with PC connect to DB9 pin 2
RS232 Rx	Input	RS232 Receive signal – for communication with PC connect to DB9 pin 3.
Lamp Enable	Output	A TTL signal that is driven Active HIGH when the Lamp Enable command is sent to the USB2000+
Continuous Strobe	Output	TTL output signal used to pulse a strobe that is divided down from the Master Clock signal
Ground	Input/Output	Ground
Single Strobe	Output	TTL output pulse used as a strobe signal, which has a programmable delay relative to the beginning of the spectrometer integration period.
ExtTrigIn	Input	The TTL input trigger signal. In External Hardware Trigger mode this is a rising edge trigger input. In Software Trigger Mode this is an Active HIGH Level signal. In External Synchronization Mode (or External hardware Level Trigger Mode) this is a clock input, which defines the integration period of the spectrometer.
SCL	Input/Output	The I2C Clock signal for communications to other I2C peripherals
SDA	Input/Output	The I2C Data signal for communications to other I2C peripherals
GPIO(0-7)	Input/Output	8 2.5V General Purpose Software Programmable Digital Inputs/Outputs
MOSI	Output	The SPI Master Out Slave In (MOSI) signal for communications to other SPI peripherals
MISO	Input	The SPI Master In Slave Out (MISO) signal for communications to other SPI peripherals
SPI CLK	Output	The SPI Clock signal for communications to other SPI peripherals
SPICS_OUT	Output	The SPI Chip/Device Select signal for communications to other SPI peripherals

CCD Overview

CCD Detector

The detector used for the USB2000+ is a charge transfer device (CCD) that has a fixed well depth (capacitor) associated with each photodetector (pixel).

Charge transfer, reset and readout initiation begin with the integration time clock going HIGH. At this point, the remaining charge in the detector wells is transferred to a shift register for serial transfer. This process is how the array is read.

The reset function recharges the photodetector wells to their full potential and allows for nearly continuous integration of the light energy during the integration time, while the data is read out through serial shift registers. At the end of an integration period, the process is repeated.

When a well is fully depleted by leakage through the back-biased photodetector, the detector is considered saturated and provides the maximum output level. The CCD is a depletion device and thus the output signal is inversely proportional to the input photons. The electronics in the USB2000+ invert and amplify this electrical signal.

CCD Well Depth

We strive for a large signal-to-noise (S:N) in optical measurements so that small signal variations can be observed and a large dynamic range is available. The S:N in photon noise-limited systems is defined and measured as the square root of the number of photons it takes to fill a well to saturation. In the USB2000+, the well depth of the CCD pixels is about 160,000 photons, providing a S:N of 400:1 (S:N can also be measured as the saturation voltage divided by near-saturation RMS noise). There is also a fixed readout noise component to all samples. The result is a system with a S:N of ~275:1.

There are two ways to achieve a large S:N (e.g., 6000:1) in CCD detectors where photon noise is predominant.

1. Use a large-well device that integrates to saturation over a long period of time until the photon noise is averaged out by the root of n multiples of a defined short Δt.

2. Use a small-well device that integrates to saturation at one short Δt and then signal average mathematically n times.

Theoretically, both approaches achieve the same results, though there are large differences in actual operation. Traditional spectroscopic instruments use large-well devices and 16-bit ADCs to achieve the defined S:N. The USB2000+ uses a small-well device and utilizes signal averaging to achieve the same S:N. A brief comparison of large and small-well devices is shown in the table below.

Well Depth Comparison

Large-well CCDs	Small-well CCDs
Low photon noise	Medium photon noise that can be averaged out
Low optical sensitivity	High optical sensitivity
High power consumption	Low power consumption
>10 MHz operating speeds	Moderate operating speeds (~2 MHz)

Signal Averaging

Signal averaging is an important tool in the measurement of spectral structures. It increases the S:N and the amplitude resolution of a set of samples. The types of signal averaging available in our software are time-based and spatial-based.

When using the time-base type of signal averaging, the S:N increases by the square root of the number of samples. Signal averaging by summing is used when spectra are fairly stable over the sample period. Thus, a S:N of 2500:1 is readily achieved by averaging 100 spectra.

Spatial averaging or pixel boxcar averaging can be used to improve S:N when observed spectral structures are broad. The traditional boxcar algorithm averages *n* pixel values on each side of a given pixel.

Time-based and spatial-based algorithms are not correlated, so therefore the improvement in S:N is the product of the two processes.

In review, large-well devices are far less sensitive than small-well devices and thus, require a longer integration time for the same output. Large-well devices achieve a good S:N because they integrate out photon noise. Small-well devices must use mathematical signal averaging to achieve the same results as large-well devices, but small-well devices can achieve the results in the *same period of time*. This kind of signal averaging was not possible in the past because analog-to-digital converters and computers were too slow.

Large-well devices consume large amounts of power, resulting in the need to build thermoelectric coolers to control temperature and reduce electronic noise. Then, even more power is required for the temperature stabilization hardware. But small-well devices only need to use signal averaging to achieve the same results as large-well devices, and have the advantages of remaining cool and less noisy.

Internal Operation

Pixel Definition

A series of pixels in the beginning of the scan have been covered with an opaque material to compensate for thermal induced drift of the baseline signal. As the USB2000+ warms up, the baseline signal will shift slowly downward a few counts depending on the external environment. The baseline signal is set at the time of manufacture. If the baseline signal is manually adjusted, it should be left high enough to allow for system drift. The following is a description of all of the pixels, both as they exist on the hardware device and as they are actually read from the device via USB:

Pixels on the Device

Pixel	Description
0–11	Not usable
12–29	Optical black pixels
30–31	Not usable
32–2079	Optical active pixels
2080–2085	Not usable

Pixels Read from the Device via USB

Pixel	Description
0–17	Optical black pixels
18–19	Not usable
20-2047	Optical active pixels

It is important to note that the USB2000+ only digitizes the first 2048 pixels.

CCD Detector Reset Operation

At the start of each integration period, the detector transfers the signal from each pixel to the readout registers and resets the pixels. The total amount of time required to perform this operation is ~8 − 9μs. The user needs to account for this time delay when the pixels are optically inactive, especially in the external triggering modes.

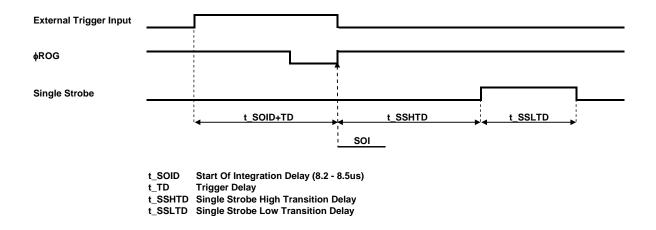# Timing Signals

Strobe Signals

Single Strobe

The Single Strobe signal is a programmable TTL pulse that occurs at a user-determined time during each integration period. This pulse has a user-defined High Transition Delay and Low Transition Delay. The pulse width of the Single Strobe is the difference between these delays. It is only active if the Lamp Enable command is active.

Synchronization of external devices to the spectrometer's integration period is accomplished with this pulse. The Strobe Delay is specified by the Single Strobe High Transition Delay (SSHTD) and the Pulse Width is specified by the Single Strobe Low Transition Delay (SSLTD) minus the Single Strobe High Transition Delay (PW = SSLTD – SSHTD). Both values are programmable in 500ns increments for the range of 0 to 65,535 (32.7675ms).

The timing of the Single Strobe is based on the Start of Integration (SOI). SOI occurs on the rising edge of ϕROG which is used to reset the Sony ILX511 detector. In all trigger modes using an External Trigger, there is a fixed relationship between the trigger and the SOI. In the Normal mode and Software Trigger mode, the SOI still marks the beginning of the Single Strobe, but due to the nondeterministic timing of the software and computer operating system, this timing will change over time and is not periodic. That is, at a constant integration time, the Single Strobe will not be periodic, but it will indicate the start of the integration. The timing diagram for the Single Strobe in External Hardware Trigger mode is shown below:

t_SOID	Start Of Integration Delay (8.2 - 8.5us)
t_TD	Trigger Delay
t_SSHTD	Single Strobe High Transition Delay
t_SSLTD	Single Strobe Low Transition Delay

Single Strobe (External Hardware Trigger/External Synchronous Trigger Mode)

The Trigger Delay (TD) is another user programmable delay which specifies the time in 500ns increments that the SOI will be delayed beyond the normal Start of Integration Delay (SOID).

An example calculation of the Single Strobe timing follows:

If the TD = 1ms, SSHTD = 50ms, and SSLTD = 70ms then, the rising edge of the Single Strobe will occur approximately 51.82ms (1ms + 50ms + 8.2us) after the External Trigger Input goes high and the Pulse Width will be 20ms (70ms – 50ms).

Continuous Strobe

The Continuous Strobe signal is a programmable frequency pulse-train with a 50% duty cycle. It is programmed by specifying the desired period whose range is 2us to 60s. This signal is continuous once enabled, but is not synchronized to the Start of Integration or External Trigger Input. The Continuous Strobe is only active if the Lamp Enable command is active.

Synchronizing Strobe Events

If the application requires more than one pulse per integration period, the user needs to insure the continuous strobe and integration period are synchronized. The integration time must be set so that an equal number of strobe events occurs during any given integration period.

Triggering Modes

The USB2000+ supports three triggering modes, (plus Normal mode), which are set with the Trigger Mode command. Detailed information of each triggering mode follows. Also refer to the External Triggering Options document for Firmware versions 3.0 and above located on our website at **http://oceanoptics.com///wp-content/uploads/External-Triggering-Options_Firmware3.0andAbove.pdf**. The following paragraphs describe these modes. For firmware version below 3.0, see **http://oceanoptics.com///wp-content/uploads/External-Triggering-Options.pdf**.

Normal

In the Normal (Free-run) mode, the spectrometer will acquire a spectrum based on the integration period specified through the software interface. This data is made available for reading as soon as all the data is stored. The spectrometer will then immediately try to acquire two additional spectra even if none have been requested. If a new spectrum request has come from the user, during either the second or third integration cycle then the appropriate spectrum will be available to the user. If a second spectrum has not been requested then the Spectrometer will not save the second or third spectrum and will go into an idle mode waiting for a new spectrum request from the user. In this scenario, a new acquisition begins when a new spectrum is requested. No further spectra are acquired until the original spectrum is read by the user.

External Synchronous Trigger Mode

In the External Synchronous Trigger mode, two external triggers are required to complete a data acquisition. The first rising edge starts the integration period and the second rising edge stops the integration and starts the next. Thus the integration time is the period between the two external trigger pulses. After the integration period, the spectrum is retrieved and available to the user. As in normal mode, no further spectra are acquired until the original spectrum is read by the user.

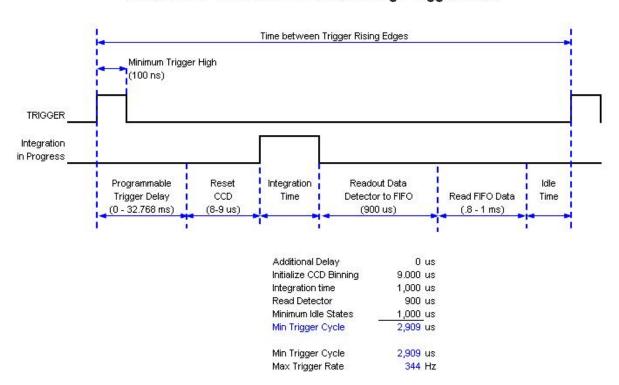## External Hardware Level Trigger Mode

In the External Hardware Level Trigger mode, a rising edge detected by the spectrometer from the External Trigger input starts the integration period specified through the software interface. After the integration period, the spectrum is retrieved and is ready to be read by the user. As long as the trigger level remains active in a logic one state, back-to-back acquisitions can occur, as in the Normal mode, until the trigger transitions to an inactive level. As in normal mode, no further spectra are acquired until the original spectrum is read by the user.

External Hardware Edge Trigger Mode

In the External Hardware Edge Trigger mode, a rising edge detected by the spectrometer from the External Trigger input starts the integration period specified through the software interface. After the integration period, the spectrum is retrieved and is ready to be read by the user. If another trigger is sent a new integration cycle will begin. If a spectrum request is not received before the integration cycle has ended then that data will be deleted and a new trigger and spectrum request is required. Only one acquisition will be performed for each External Trigger pulse, no matter what the pulse's duration is. No further spectra are acquired until the original spectrum is read by the user.

USB2000+ -- Timetable for Hardware Edge Trigger Mode

Additional Delay	0 us
Initialize CCD Binning	9.000 us
Integration time	1,000 us
Read Detector	900 us
Minimum Idle States	1,000 us
Min Trigger Cycle	2,909 us
Min Trigger Cycle	2,909 us
Max Trigger Rate	344 Hz

Digital Inputs & Outputs

General Purpose Inputs/Outputs (GPIO)

The USB2000+ has 8 user programmable 2.5V TTL digital Input/Output pins, which can be accessed at the 22-pin accessory connector. Through software, the state of these I/O pins can be defined and used for multi-purpose applications such as communications buses, sending digital values to an LCD/LED display, or even implementing complex feedback systems.

GPIO Recommended Operating Levels:

VIL(max) = 0.7V

VIH(min) = 1.7V

IOL = 24mA

IOH = -24mA

GPIO Absolute Maximum Ratings are as follows:

VIN(min) = -0.5V

VIN(max) = 3.0V

Communication and Interface

USB 2.0

480-Mbit **U**niversal **S**erial **B**us allows for ultra fast data transfer. This is the main communication standard for PC users. The USB BUS also provides power as well as communications over a single cord. Thereby allowing the USB2000+ to operate anywhere you can take a laptop computer without any bulky external power supplies.

RS-232

Also known as serial port communication, RS232 is a standard in PC and industrial device communications. Using transmit and receive signals this option allows the USB2000+ to be a standalone device, which can output data to other logic devices/controllers such as a PLC or microcontroller. The USB2000+ requires an external 5-Volt power source when operating in RS-232 mode.

I²C

Inter-**I**ntegrated **C**ircuit 2-Wire serial BUS is widely used in embedded systems applications. With I²C you can add peripherals to your system without using valuable resources like I/O ports.

SPI

Serial **P**eripheral **I**nterface is also a widely used communication standard in embedded systems applications. It is a 3-wire interface that can be used to communicate to multiple slave devices.

USB2000+ USB Port Interface Communications and Control Information

Overview

The USB2000+ is a microcontroller-based Miniature Fiber Optic Spectrometer that can communicate via the Universal Serial Bus or RS-232. This section contains the necessary command information for controlling the USB200 via the USB interface. This information is only pertinent to users who wish to not utilize Ocean Optics 32 bit driver to interface to the USB2000+. Only experienced USB programmers should attempt to interface to the USB2000+ via these methods.

Hardware Description

The USB2000+ utilizes a Cypress CY7C68013 microcontroller that has a high speed 8051 combined with an USB2.0 ASIC. Program code and data coefficients are stored in external E^2PROM that are loaded at boot-up via the I^2C bus. The microcontroller has 16K of internal SRAM and 64K of external SRAM. Maximum throughput for spectral data is achieved when data flows directly from the external FIFO's directly across the USB bus. In this mode the 8051 does not have access to the data and thus no manipulation of the data is possible.

USB Information

Ocean Optics Vendor ID number is 0x2457 and the Product ID is 0x101E.

Instruction Set

Command Syntax

The list of the commands is shown in the following table followed by a detailed description of each command. The length of the data depends on the command. All commands are sent to the USB2000+ through End Point 1 Out (EP1). All spectra data is acquired through End Point 2 In and all other queries are retrieved through End Point 1 In (EP1). The endpoints enabled and their order is:

Pipe #	Description	Type	Hi Speed Size (Bytes)	Full Speed Size (Bytes)	Endpoint Address
0	End Point 1 Out	Bulk		64	0x01
1	End Point 2 In	Bulk		512	0x82
2	End Point 6 In	Bulk		512	0x86
3	End Point 1 In	Bulk		64	0x81

USB Command Summary

EP1 Command Byte Value	Description	Version
0x01	Initialize USB2000+	0.90.0
0x02	Set Integration Time	0.90.0
0x03	Set Strobe Enable Status	0.90.0
0x04	Set Shutdown Mode	0.90.0
0x05	Query Information	0.90.0
0x06	Write Information	0.90.0
0x09	Request Spectra	0.90.0
0x0A	Set Trigger Mode	0.90.0
0x0B	Query number of Plug-in Accessories Present	0.90.0
0x0C	Query Plug-in Identifiers	0.90.0
0x0D	Detect Plug-ins	0.90.0
0x60	General I^{2}C Read	0.90.0
0x61	General I^{2}C Write	0.90.0
0x62	General SPI I/O	0.90.0
0x6A	Write Register Information	0.90.0
0x6B	Read Register Information	0.90.0
0x6C	Read PCB Temperature	0.90.0
0x6D	Read Irradiance Calibration Factors	0.90.0
0x6E	Write Irradiance Calibration Factors	0.90.0
0xFE	Query Information	0.90.0

USB Command Descriptions

A detailed description of all USB2000+ commands follows. While all commands are sent to EP1 over the USB port, the byte sequence is command dependent. The general format is the first byte is the command value and the additional bytes are command specific values.

Byte 0	Byte 1	Byte 2	…	Byte n-1
Command Byte	Command Specific	Command Specific	…	Command Specific

Initialize USB2000+

Initializes certain parameters on the USB2000+ and sets internal variables based on the USB communication speed the device is operating at. This command should be called at the start of every session however if the user does not call it, it will be executed on the first Request Scan command. The default values are set as follows:

Parameter	Default Value
Trigger Mode	0 – Normal Trigger

Byte Format

Byte 0
0x01

Set Integration Time

Sets the USB2000+ integration time in microseconds. The value is a 32-bit value whose acceptable range is 1,000µs – 65,535,000µs. If the value is outside this range the value is unchanged. For integration times less than 655,000us, the integration counter has a resolution of 10us. For integration times greater than this the integration counter has a resolution of 1ms.

Byte Format

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4
0x02	LSW-LSB	LSW-MSB	MSW-LSB	MSW-MSB

MSW & LSW: Most/Least Significant Word
MSB & LSB: Most/Least Significant Byte

Set Strobe Enable Status

Sets the USB2000+ Lamp Enable line (J2 pin 4) as follows. The Single Strobe and Continuous Strobe signals are enabled/disabled by this Lamp Enable Signal.

Data Byte = 0 ➔ Lamp Enable Low/Off

Data Byte = 1 ➔ Lamp Enable HIGH/On

Byte Format

Byte 0	Byte 1	Byte 2
0x03	Data byte LSB	Data Byte MSB

Set Shutdown Mode

Sets the USB2000+ shutdown mode. When shutdown, the internal FX2 microcontroller is continuously running however all other functionality is disabled. In this power down mode the current consumption is reduced to 250mA (operating current for the FX2 microcontroller). When shutdown is active (active low), the external 5V signal (V5_Switched pin 3) is disabled in addition to all other signals except I^2C lines.

Data Byte = 0 ➜ Shutdown everything but the FX2

Data Byte = !0 ➜ Power up entire Spectrometer

Byte Format

Byte 0	Byte 1	Byte 2
0x04	Data byte LSB	Data Byte MSB

Query Information

Queries any of the 20 stored spectrometer configuration variables. The Query command is sent to End Point 1 Out and the data is retrieved through End Point 1 In. When using Query Information to read EEPROM slots, data is returned as ASCII text. However, everything after the first byte that is equal to numerical zero will be returned as garbage and should be ignored.

The 20 configuration variables are indexed as follows:

Configuration Idex - Description

0 – Serial Number

1 – 0th order Wavelength Calibration Coefficient

2 – 1st order Wavelength Calibration Coefficient

3 – 2nd order Wavelength Calibration Coefficient

4 – 3rd order Wavelength Calibration Coefficient

5 – Stray light constant

6 – 0th order non-linearity correction coefficient

7 – 1st order non-linearity correction coefficient

8 – 2nd order non-linearity correction coefficient

9 – 3rd order non-linearity correction coefficient

10 – 4th order non-linearity correction coefficient

11 – 5th order non-linearity correction coefficient

12 – 6th order non-linearity correction coefficient

13 – 7th order non-linearity correction coefficient

14 – Polynomial order of non-linearity calibration

15 – Optical bench configuration: gg fff sss

gg – Grating #, fff – filter wavelength, sss – slit size

16 – USB2000+ configuration: AWL V

A – Array coating Mfg, W – Array wavelength (VIS, UV, OFLV), L – L2 lens installed, V – CPLD Version

17 – Reserved

18 – Reserved

19 – Reserved

Byte Format

Byte 0	Byte 1
0x05	Configuration Index

Return Format (EP1)

The data is returned in ASCII format and read in by the host through End Point 1.

Byte 0	Byte 1	Byte 2	Byte 3	…	Byte 16
0x05	Configuration Index	ASCII byte 0	ASCII byte 1	…	ASCII byte 14

Write Information

Writes any of the 19 stored spectrometer configuration variables to EEPROM. The 19 configuration variables are indexed as described in the Query Information. The information to be written is transferred as ASCII information.

Byte Format

Byte 0	Byte 1	Byte 2	Byte 3	…	Byte 16

0x06	Configuration Index	ASCII byte 0	ASCII byte 1	…	ASCII byte 14

Request Spectra

Initiates spectra acquisition. The USB2000+ will acquire a complete spectrum (2048 pixel values). The data is returned in bulk transfer mode through EP2. The table below provides the pixel order overview for the 2 different speeds. The pixel values are decoded as described below.

Byte Format

Byte 0
0x09

Return Format

The format for the returned spectral data is dependant upon the USB communication speed. The format for both High Speed (480 Mbps) and Full Speed (12Mbps) is shown below. All pixel values are 16 bit values which are organized in LSB | MSB order. There is an additional packet containing one value that is used as a flag to insure proper synchronization between the PC and USB2000+.

USB High Speed (480Mbps) Packet Format

The data is read from EP2In. The packet format is described below.

Packet #	End Point	# Bytes	Pixels
0	EP2In	512	0-255
1	EP2In	512	256-511
2	EP2In	512	512-767
3	EP2In	512	768-1023
4	EP2In	512	1024-1279
5	EP2In	512	1280-1535
…	EP2In	512	
7	EP2In	512	1792–2048
8	EP2In	1	Sync Packet

The format for the first packet is as follows (all other packets except the synch packet has a similar format except the pixel numbers are incremented by 256 pixels for each packet).

Packet 0

Byte 0	Byte 1	Byte 2	Byte 3
Pixel 0 LSB	Pixel 0 MSB	Pixel 1 LSB	Pixel 1 MSB
…			
		Byte 510	Byte 511

		Pixel 255 LSB	Pixel 255 MSB

Packet 15 – Synchronization Packet (1 byte)

Byte 0
0x69

USB Full Speed (12Mbps) Packet Format

In this mode all data is read from EP2In. The pixel and packet format is shown below.

Packet #	End Point	# Bytes	Pixels
0	EP2In	64	0-31
1	EP2In	64	32-63
2	EP2In	64	64-95
…	EP2In	64	
63	EP2In	64	2016-2047
64	EP2In	1	Sync Packet

Packet 0

Byte 0	Byte 1	Byte 2	Byte 3
Pixel 0 LSB	Pixel 0 MSB	Pixel 1 LSB	Pixel 2 MSB

…

		Byte 62	Byte 63
		Pixel 31 LSB	Pixel 31 MSB

Packet 64 – Synchronization Packet (1 byte)

Byte 0
0x69

Autonulling

Slot 0x11 (17) contains autonulling information that has a scaling term used to adjust the magnitude of the entire spectrum. This can be read out by sending bytes 0x05 11 to the low-speed out endpoint (0x01) and then reading out 17 bytes from the low-speed in endpoint (0x81). The bytes of use are Byte offset 6 and 7. The 17 bytes will be formatted as follows:

0x05 11 XX XX XX XX SS SS XX XX XX XX XX XX XX XX XX

Where:

XX = reserved bytes (most are either unused or are only used internally to the device)

SS = saturation level of the device as two bytes (LSB followed by MSB).

These need to be assembled into a single 16-bit value. Any time that a spectrum is read from the spectrometer, each pixel's intensity value should be multiplied by (65535.0/saturation_level) to set the scale appropriately.

The contents of slot 0x11 are set at the factory and should not be altered.

Set Trigger Mode

Sets the USB2000+ Trigger mode to one of five states. If an unacceptable value is passed then the trigger state is unchanged (refer to the External Triggering Options Instructions for a description of the trigger modes).

> Data Value = 0 ➜ Normal (Free running) Mode
> Data Value = 1 ➜ External Hardware Level Trigger Mode
> Data Value = 2 ➜ External Synchronization Trigger Mode
> Data Value = 3 ➜ External Hardware Edge Trigger Mode

Byte Format

Byte 0	Byte 1	Byte 2
0x0A	Data Value LSB	Data Value MSB

Query Number of Plug-in Accessories

To query the number of preset plug-in accessories, use the Query Plug-in Identifiers command 0x0C (below), matching plug-in IDs to the known IDs.

Query Plug-in Identifiers

Queries the Plug-in accessories identifiers. This command returns 7 bytes with the last byte always being zero at this point. Each of the first 6 bytes correspond to Ocean Optics compatible devices which responded appropriately for I^2C addresses 2 through 7 respectively. The I^2C addresses are reserved for various categories of devices and the value for each category is shown below. I^2C addresses 0-1 are reserved for loading program code from EEPROMS

Byte Format

Byte 0
0x0C

Return Format

The data is returned in Binary format and read in by the host through End Point 7.

Byte 0	Byte 1	...	Byte 5	Byte 6
Value @ I^2C address 2	Value @ I^2C address 3	...	Value @ I^2C address 7	0x00

Detect Plug-ins

Reads all of the plug-in accessories that are plugged into the I^{2}C bus. No data values are returned.

Byte Format

Byte 0
0x0D

General I^{2}C Read

Performs a general purpose read on the I^{2}C pins for interfacing to attached peripherals. The time to complete the command is determined by the amount of data transferred and the response time of the peripheral. The I^{2}C bus runs at 400KHz. The maximum number of bytes that can be read is 61.

Command Byte Format

Byte 0	Byte 1	Byte 2
0x60	I^{2}C Address	Bytes to Read

Return Byte Format

Byte 0	Byte 1	Byte 2	Byte 3	…	Byte N+3
I^{2}C Results	I^{2}C Address	Bytes to Read	Data Byte 0	…	Data byte N

I^{2}C Result Value	Description
0	I^{2}C bus Idle
1	I^{2}C bus Sending Data
2	I^{2}C bus Receiving Data
3	I^{2}C bus Receiving first byte of string
5	I^{2}C bus in waiting for STOP condition
6	I^{2}C experienced Bit Error
7	I^{2}C experience a Not Acknowledge (NAK) Condition
8	I^{2}C experienced successful transfer
9	I^{2}C bus timed out

General I^{2}C Write

Performs a general purpose write on the I^{2}C pins for interfacing to attached peripherals. The time to complete the command is determined by the amount of data transferred and the response time of the peripheral. In all I2C communications, the first byte of the transaction consists of a 7 bit address and a read/write bit. The "address" that is passed as the second byte of the I2C write command is this 7 bit address, which will be shifted 1 bit left and appended with the R/W bit to form the first byte of the I2C write transaction. The I^{2}C bus runs at 400KHz. The results codes are described above.

Command Byte Format

Byte 0	Byte 1	Byte 2	Byte 3	...	Byte N+3
0x61	I²C Address	Bytes to Write	Data Byte 0	…	Data byte N

Return Byte Format

Byte 0
I²C Results

General SPI Input/Output

Performs a general-purpose write and read on the SPI bus for interfacing to attached peripherals. The time to complete the command is determined by the amount of data transferred and the response time of the peripheral. Wait at least 10 ms after sending a Write command before reading the Return value. The SPI bus runs at ~125KHz Clock. The maximum number of bytes that can be written or read is 61. During this transfer the SPI Chip Select signal is driven to an active LOW TTL level. Data is transmitted out the MOSI (Master Out Slave In) line on the rising edge of the clock signal. Data is also latched in the from the MISO line on the falling edge of the clock signal.

Command Byte Format

Byte 0	Byte 1	Byte 2	Byte 3	...	Byte N+2
0x62	# of Bytes (N)	Write Byte 0	Write Byte 1	…	Write Byte N

Return Byte Format

Byte 0	Byte 1	Byte 2	...	Byte N+1
# of Bytes (N)	Read Byte 0	Read Byte 1	…	Read Byte N

Write Register Information

Most all of the controllable parameters for the USB2000+ are accessible through this command (e.g., GPIO, strobe parameters, etc). A complete list of these parameters with the associate register information is shown in the table below. Commands are written to End Point 1 Out typically with 4 bytes (some commands may require more data bytes). All data values are 16 bit values transferred in LSB | MSB order. This command requires 100us to complete; the calling program needs to delay for this length of time before issuing another command. In some instances, other commands will also write to these registers (i.e., integration time), in these cases the user has the options of setting the parameters through 2 different methods.

Byte Format

Byte 0	Byte 1	Byte 2	Byte 3
0x6A	Register Value	Data Byte LSB	Data Byte MSB

Register Address	Description	Default Value	Min Value	Max Value	Time Base
0x00[*]	Master Clock Counter Divisor	24	1	0xFFFF	48MHz
0x04	FPGA Firmware Version (Read Only)				
0x08	Continuous Strobe Timer Interval Divisor	48000	0	0xFFFF	Continuous Strobe Base Clock (see Register 0x0C)
0x0C	Continuous Strobe Base Clock Divisor	4800	0	0xFFFF	48MHz
0x0C	Continuous Strobe LSB Register	4800	0	0xFFFF	48MHz
0x10[*]	Integration Period Base Clock Divisor	480	0	0xFFFF	48MHz
0x10[*]	Integration Period LSB Register	480	0	0xFFFF	1KHz
0x14	Set base_clk or base_clkx2 0: base_clk 1: base_clkx2	0	0	1	N/A
0x18[*]	Integration Clock Timer Divisor	600	0	0xFFFF	Integration Period Base Clock (see Register 0x10)
0x18[*]	Integration Period MSB Register				
0x20	Reserved				
0x28	Hardware Trigger Delay – Number of Master Clock cycles to delay when in External Hardware Trigger mode before the start of the integration period	0	0	0xFFFF	
0x28	Hardware Trigger Delay – Delay the start of integration from the rising edge of the trigger in 500ns increments	0	0	0xFFFF	
0x2C[&*]	Trigger Mode 0 = Free Running 1 = Software Trigger 2 = External Hardware Trigger 3 = External Synchronization Trigger	0	0	3	

Register Address	Description	Default Value	Min Value	Max Value	Time Base
0x2C&*	Trigger Mode 0 = Free Running 1 = External Hardware Level Trigger 2 = External Synchronization Trigger 3 = External Hardware Edge Trigger	0	0	3	N/A
0x30	Reserved				
0x38	Single Strobe High Clock Transition Delay Count	1	0	0xFFFF	2MHz
0x3C	Single Strobe Low Clock Transition Delay Count	5	0	0xFFFF	2MHz
0x40	Lamp Enable	0	0	1	N/A
0x48	GPIO Mux Register 0: pin is GPIO pin 1: pin is alternate function	0	0	0x03FF	N/A
0x50	GPIO Output Enable 1: pin is output 0: pin is input	0	0	0x03FF	N/A
0x54	GPIO Data Register For Ouput: Write value of signal For Input: Read current GPIO state	0	0	0x03FF	N/A
0x58	Reserved				
0x5C	Offset Value	0	0	0xFFFF	N/A
0x60	Offset Control Bit 0 = Enable Auto-Nulling Bit 1 = Enable Auto-Nulling Saturation	0	0	0xFFFF	N/A
0x64	FPGA Programmed (Read Only)	0x5501	N/A	N/A	N/A
0x68	Maximum Saturation Level	0x55F0	0	0xFFFF	N/A

Notes: * - User should not change these values because spectrometer performance can be affected. This information is included just for completeness

& - These values are controlled by other command interfaces to the USB2000+ (i.e., Set integration time command).

Read Register Information

Read the values from any of the registers above. This command is sent to End Point 1 Out and the data is retrieved through End Point 1 In.

Byte Format

Byte 0	Byte 1
0x6B	Register Value

Return Format (EP1In)

Byte 0	Byte 1	Byte 2
Register Value	Value LSB	Value MSB

Read PCB Temperature

Read the Printed Circuit Board Temperature. The USB2000+ contains an DS1721 temperature sensor chip which is mounted to the under side of the PCB. This command is sent to End Point 1 Out and the data is retrieved through End Point 1 In. The value returned is a signed 16-bit A/D conversion value, which is equated to temperature by:

$$\text{Temperature (}^{o}\text{C)} = .003906 * \text{ADC Value}$$

Byte Format

Byte 0
0x6C

Return Format (EP1In)

Byte 0	Byte 1	Byte 2
Read Result	ADC Value LSB	ADC Value MSB

If the operation was successful, the Read Result byte value will be 0x08. All other values indicate the operation was unsuccessful.

Read Irradiance Factors

Reads 60 bytes of data, which is utilized for Irradiance Calibration information from the desired EEPROM memory address.

Byte Format

Byte 0	Byte 1	Byte 2
0x6D	EEPROM Address LSB	EEPROM Address MSB

Return Byte Format

Byte 0	Byte 1	…	Byte 59
Byte 0	Byte 1	…	Byte 59

Write Irradiance Factors

Write 60 bytes of data, which is utilized for Irradiance Calibration information to the desired EEPROM memory address.

Byte Format

Byte 0	Byte 1	Byte 2	Byte 3	…	Byte 62
0x6E	EEPROM Address LSB	EEPROM Address MSB	Byte 0	…	Byte 59

Query Status

Returns a packet of information containing the current operating information. Packet structure is given below:

Byte Format

Byte 0
0xFE

Return Format

The data is returned in Binary format and read in by the host through End Point 1 In. The structure for the return information is as follows:

Byte	Description	Comments
0-1	Number of Pixels - WORD	LSB | MSB order
2-5	Integration Time - WORD	Integration time in μs – LSW | MSW. Within each word order is LSB | MSB
6	Lamp Enable	0 – Signal LOW 1 – Signal HIGH
7	Trigger Mode Value	
8	Spectral Acquisition Status	
9	Packets In Spectra	Returns the number of Packets in a Request Spectra Command.
10	Power Down Flag	0 – Circuit is powered down 1 – Circuit is powered up
11	Packet Count	Number of packets loaded into End Point Memory
12	Reserved	
13	Reserved	
14	USB Communications Speed	0 – Full Speed (12Mbs) 0x80 – High Speed (480 Mbps)
15	Reserved	

Appendix A: USB2000+ Serial Port Interface Communications and Control Information

Overview

The USB2000+ is a microcontroller-based Miniature Fiber Optic, which can communicate via the Universal Serial Bus or RS-232. This document contains the necessary command information for controlling the USB2000+ via the RS-232 interface.

Hardware Description

Overview

The USB2000+ utilizes a Cypress FX2 microcontroller, which has a high speed 8051, combined with an USB ASIC. Program code and data coefficients are stored in external E^{2}PROM, which are loaded at boot-up via the I^{2}C bus.

Instruction Set

Command Syntax

The list of the commands are shown in the following table along with the microcode version number they were introduced with. All commands consist of an ASCII character passed over the serial port, followed by some data. The length of the data depends on the command. The format for the data is either ASCII or binary (default). The ASCII mode is set with the "a" command and the binary mode with the "b" command. To insure accurate communications, all commands respond with an ACK (ASCII 6) for an acceptable command or a NAK (ASCII 21) for an unacceptable command (i.e. data value specified out of range).

In the ASCII data value mode, the USB2000+ "echoes" the command back out the RS-232 port. In binary mode all data, except where noted, passes as 16-bit unsigned integers (WORDs) with the MSB followed by the LSB. By issuing the "v command" (Version number query), the data mode can be determined by viewing the response (ASCII or binary).

In a typical data acquisition session, the user sends commands to implement the desired spectral acquisition parameters (integration time, etc.). Then the user sends commands to acquire spectra (S command) with the previously set parameters. If necessary, the baud rate can be changed at the beginning of this sequence to speed up the data transmission process.

Upgrading from USB2000

Below are a summary of the changes that may be required if you are upgrading from a USB2000 to USB2000+

- Baud rates
    - The startup baud rate is programmable through the EEPROM Calibration Entry #18
    - The unit operates at 115.2K Baud, but does not run at 57.6K Baud
- Operating Parameters
    - The I (upper case) command will set the integration time in milliseconds
    - To take advantage of the microsecond integration time capability, use the i (lower case) command
    - Most new operating parameters are set through the FPGA (W command)
- Spectral Data
    - If only one spectra is "Accumulated", then data is returned in 16 bit format
    - If additional spectra is "Accumulated", then data is returned in 32 bit format
    - The limitation of "Accumulating" 15 spectra is eliminated

RS232 Command Summary

Letter	Description
A	Adds scans
B	Set Pixel Boxcar
C	
D	
E	
F	***Non functional but follows SAD500 command format***
G	Set Data Compression
H	***Non functional but follows SAD500 command format***
I	Sets integration time
J	Sets Lamp Enable Line
K	Changes baud rate

Letter	Description
L	Clear Memory
M	Set Data Storage Mode
N	
O	
P	Partial Pixel Mode
Q	
R	
S	Starts spectral acquisition with previously set parameters
T	Sets trigger mode
U	
V	
W	Query scans in memory
X	
Y	
Z	Read out Scan from memory
A	Set ASCII mode for data values
b	Set binary mode for data values
k	Sets Checksum mode
o	Oxygen (USB-LS-450) related commands
t	Temperature in hundredths of degrees C
u	Set Oxygen Calibration Coefficients
v	Provides microcode version #
x	Sets calibration coefficients
y	Sets 16-bit timer operation
?	Queries parameter values
+	Reads the plugged-in accessories
_	USB2000 Identifier

Command Descriptions

A detailed description of all USB2000+ commands follows. The {} indicates a data value which is interpreted as either ASCII or binary (default). The default value indicates the value of the parameter upon power up.

Add Scans

Sets the number of discrete spectra to be summed together. Since the USB2000+ has the ability to return 32 bit values, overflow of the raw 16 bit ADC value is not a concern.

Command Syntax:	A{DATA WORD}
Response:	ACK or NAK
Range:	1-5000
Default value:	1

Pixel Boxcar Width

Sets the number of pixels to be averaged together. A value of *n* specifies the averaging of *n* pixels to the right and *n* pixels to the left. This routine uses 32-bit integers so that intermediate overflow will not occur; however, the result is truncated to a 16-bit integer prior to transmission of the data. This math is performed just prior to each pixel value being transmitted out. Values greater than ~3 will exceed the idle time between values and slow down the overall transfer process.

Command Syntax:	B{DATA WORD}
Response:	ACK or NAK
Range:	0-15
Default value:	0

Set Data Compression

Specifies whether the data transmitted from the USB2000+ should be compressed to speed data transfer rates.

Command Syntax:	G{DATA WORD}
Response:	ACK or NAK
Range:	0 – Compression off !0 – Compression on
Default value:	0

Integration Time (16 bit)

Sets the USB2000+'s integration time, in milliseconds, to the value specified. This command is the same as on the USB2000.

Command Syntax:	I{16 bit DATA WORD}
Response:	ACK or NAK
Range:	1 - 65000
Default value:	10

Integration Time (32 bit)

Sets the USB2000+'s integration time, in microseconds, to the value specified.

Command Syntax:	i{32 bit DATA WORD}
Response:	ACK or NAK
Range:	1000 – 65,000,000
Default value:	10,000

Lamp Enable

Sets the USB2000+'s Lamp Enable line to the value specified

Command Syntax:	J{DATA WORD}
Value:	0 = Light source/strobe off—Lamp Enable low 1 = Light source/strobe on—Lamp Enable high
Response:	ACK or NAK
Default value:	0

Baud Rate

Sets the USB2000+'s baud rate.

Command Syntax:	K{DATA WORD}			
Value:	0=2400 1=4800 2=9600			
	3=19200	4=38400	5=Not Supported	6=115,200
Response:	See below			
Default value:	2			

When changing baud rates, the following sequence must be followed:

1. Controlling program sends K with desired baud rate, communicating at the old baud rate

2. A/D responds with ACK at old baud rate, otherwise it responds with NAK and the process is aborted

3. Controlling program waits longer than 50 milliseconds

4. Controlling program sends K with desired baud rate, communicating at the new baud rate

5. A/D responds with ACK at new baud rate, otherwise it responds with NAK and old baud rate is used

❗ If a deviation occurs at any step, the previous baud rate is utilized.

Clear Memory

Clears the spectral data memory based on the valued specified. Clearing memory is immediate since only pointer values are reinitialized.

Caution: All stored spectra are lost when the Clear memory command is executed.

Command Syntax:	L{DATA WORD}
Value:	0= Clear spectral memory 1= Clear spectral memory
Response:	ACK or NAK
Default value:	N/A

Data Storage Mode

Sets the data storage mode for future spectral acquisitions.

Command Syntax:	M{DATA WORD}
Value:	0= Scans transmitted through the serial port 1= Scans stored in spectral memory and not transmitted
Response:	ACK or NAK
Default value:	0

Pixel Mode

Specifies which pixels are transmitted. While all pixels are acquired on every scan, this parameter determines which pixels will be transmitted out the serial port.

Command Syntax:	P{DATA WORD}	
Value:	Description 0 = all 2048 pixels 1 = every n^{th} pixel with no averaging 2 = N/A 3 = pixel x through y every n pixels 4 = up to 10 randomly selected pixels between 0 and 2047 (denoted p1, p2, … p10)	Example P 0 (spaces for clarity only) P 1<Enter> N<Enter> P 2 N/A P3<Enter> x<Enter> y<Enter> n<Enter> P 4<Enter> n<Enter> p1<Enter> p2<Enter> p3<Enter> … p10<Enter>
Response:	ACK or NAK	
Default value:	0	

! Since most applications only require a subset of the spectrum, this mode can greatly
• reduce the amount of time required to transmit a spectrum while still providing all of the
desired data. This mode is helpful when interfacing to PLCs or other processing
equipment.

Spectral Acquisition

Acquires spectra with the current set of operating parameters. When executed, this command
determines the amount of memory required. If sufficient memory does not exist, an ETX (ASCII 3) is
immediately returned and no spectra are acquired. An STX (ASCII 2) is sent once the data is acquired
and stored. If the Data Storage Mode value is 0, then the data is transmitted immediately.

Command Syntax:	S
Response:	If successful, STX followed by data
	If unsuccessful, ETX

The format of returned spectra includes a header to indicate scan number, channel number, pixel
mode, etc. The format is as follows:

WORD 0xFFFF – start of spectrum
WORD Data size flag (0→Data is WORD's, 1→Data is DWORD's)
WORD Number of Scans Accumulated
WORD Integration time in milliseconds
WORD FPGA Established Baseline value (MSW)
WORD FPGA Established Baseline value (MSW)
WORD pixel mode
WORDs if pixel mode not 0, indicates parameters passed to the Pixel Mode command (P)
(D)WORDs spectral data depending on Data size flag
WORD 0xFFFD – end of spectrum

Trigger Mode

Sets the USB2000+'s external trigger mode to the value specified.

Command Syntax:	T{DATA WORD}
Value:	0 = Normal (Free running) Mode
	1 = Software Trigger Mode
	2 = External Hardware Level Trigger Mode
	3 = External Synchronization Trigger Mode
	4 = External Hardware Edge Trigger Mode
Response:	ACK or NAK
Default value:	0

Set FPGA Register Value

Sets the appropriate register within the FPGA. The list of register setting is in the USB command set
information. This command requires two data values, one to specify the register and the next to
specify the value.

Command Syntax:	W{DATA WORD 1}{DATA WORD 2}
Value:	Data Word 1 – FPGA Register address Data Word 2 – FPGA Register Value
Response:	ACK or NAK
Default value:	N/A

ASCII Data Mode

Sets the mode in which data values are interpreted to be ASCII. Only unsigned integer values (0 – 65535) are allowed in this mode and the data values are terminated with a carriage return (ASCII 13) or linefeed (ASCII 10). In this mode the USB2000+ "echoes" the command and data values back out the RS-232 port.

Command Syntax:	aA
Response:	ACK or NAK
Default value	N/A

The command requires that the string "aA" be sent without any CR or LF. This is an attempt to insure that this mode is not entered inadvertently.
A legible response to the Version number query (v command) indicates the USB2000+ is in the ASCII data mode.

Binary Data Mode

Sets the mode in which data values are interpreted to be binary. Only 16 bit unsigned integer values (0 – 65535) are allowed in this mode with the MSB followed by the LSB

Command Syntax:	bB
Response:	ACK or NAK
Default value	Default at power up – not changed by Q command

The command requires that the string "bB" be sent without any CR or LF. This is an attempt to insure that this mode is not entered inadvertently.

Checksum Mode

Specifies whether the USB2000+ will generate and transmit a 16-bit checksum of the spectral data. This checksum can be used to test the validity of the spectral data, and its use is recommended when reliable data scans are required. See Technical Note 2 for more information on checksum calculation.

Command Syntax:	k{DATA WORD}
Value:	0 = Do not transmit checksum value !0 = transmit checksum value at end of scan
Response:	ACK or NAK
Default value:	0

Version Number Query

Returns the version number of the code running on the microcontroller. A returned value of 1000 is interpreted as 1.00.0.

Command Syntax:	v
Response:	ACK followed by {DATA WORD}
Default value	N/A

Calibration Constants

Writes one of the 16 possible calibration constant to EEPROM. The calibration constant is specified by the first DATA WORD which follows the x. The calibration constant is stored as an ASCII string with a max length of 15 characters. The string is not check to see if it makes sense.

Command Syntax:	x{DATA WORD}{ASCII STRING}
Value:	DATA WORD Index description 0 – Serial Number 1 – 0th order Wavelength Calibration Coefficient 2 – 1st order Wavelength Calibration Coefficient 3 – 2nd order Wavelength Calibration Coefficient 4 – 3rd order Wavelength Calibration Coefficient 5 – Stray light constant 6 – 0th order non-linearity correction coefficient 7 – 1st order non-linearity correction coefficient 8 – 2nd order non-linearity correction coefficient 9 – 3rd order non-linearity correction coefficient 10 – 4th order non-linearity correction coefficient 11 – 5th order non-linearity correction coefficient 12 – 6th order non-linearity correction coefficient 13 – 7th order non-linearity correction coefficient 14 – Polynomial order of non-linearity calibration 15 – Optical bench configuration: gg fff sss gg – Grating #, fff – filter wavelength, sss – slit size 16 – USB2000+ configuration: AWL V A – Array coating Mfg, W – Array wavelength (VIS, UV, OFLV), L – L2 lens installed, V – CPLD Version 17 – Reserved 18 – Reserved 19 – Reserved
Response:	ACK or NAK
Default value:	N/A

To query the constants, use the ?x{DATA WORD} format to specify the desired constant

Query Variable

Returns the current value of the parameter specified. The syntax of this command requires two ASCII characters. The second ASCII character corresponds to the command character which sets the parameter of interest (acceptable values are B, A, I, K, T, J, y). A special case of this command is ?x (lower case) which requires an additional data word bee passed to indicate which calibration constant is to be queried.

Command Syntax:	?{ASCII character}
Response:	ACK followed by {DATA WORD}
Default value:	N/A

Examples

Below are examples on how to use some of the commands. Commands are in **BOLD** and descriptions are   in parenthesis. For clarity, the commands are shown in the ASCII mode (a command) instead of the default binary mode. In ASCII mode, the USB2000+ transmits a "> " prompt that is usefule to determine when it is ready to accept a command.

The desired operating conditions are: acquire spectra from the spectrometer with a 20.150ms integration time, set number of scan to add to 5 and operate at 115,200 Baud.

aA	(Set ASCII Data Mode)
>**K6<CR>**	(Start baud rate change to 115,200)
	Wait for ACK, change to 115200, wait for 20ms
>**K6<CR>**	(Verify command, communicate at 115200)
>**A5<CR>**	(Add 5 spectra)
>**i20150<CR>**	(Set integration time to 20.150ms)
S	(Acquire spectra)
…	Repeat as necessary

Application Tips

- During the software development phase of a project, the operating parameters of the USB2000+ may become out-of-synch with the controlling program. It is good practice to cycle power on the USB2000+ when errors occur.

- If you question the state of the USB2000+, you can transmit a space (or another non-command) using a terminal emulator. If you receive a NAK, the USB2000+ is awaiting a command; otherwise, it is still completing the previous command.

- For Windows users, use HyperTerminal as a terminal emulator after selecting the following:

    1.   Select **File | Properties**.

2.   Under **Connect using**, select **Direct to Com x**.

3.   Click **Configure** and match the following **Port Settings**:

   a.   Bits per second (Baud rate): Set to desired rate

   b.   Data bits: 8

   c.   Parity: None

   d.   Stop bits: 1

   e.   Flow control: None

4.   Click **OK** in **Port Settings** and in **Properties** dialog boxes.