830 Douglas Ave.
Dunedin, FL 34698
(727)733-2447
Fax:(727)733-3962
www.OceanOptics.com

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HR4000 Data Sheet

Description

The Ocean Optics HR4000 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 HR4000 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 HR4000 interfaces to PC's, PLC's 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 HR4000.

The detector used in the HR4000 spectrometer is a high-sensitivity 3648-element CCD array from Toshiba, product number TCD1304AP. (For complete details on this detector, visit Toshiba's web site at www.toshiba.com. Ocean Optics applies a coating to all TCD1304AP detectors, so the optical sensitivity could vary from that specified in the Toshiba datasheet).

The HR4000 operates off of a single +5VDC supply and either a USB or RS-232 interface. The HR4000 is a microcontroller-controlled spectrometer, thus all operating parameters are implemented through software interfacing to the unit.

Features

- TCD1304AP Detector
  - High sensitivity detector
  - Readout Rate: 1MHz
  - Shutter mode
- Optics
  - An optical resolution of ~0.03nm (FWHM)
  - A wide variety of optics available

- 14 gratings
- 6 slit widths
- 1 order sorting filter

- Electrical Performance
  - 14 bit, 5MHz A/D Converter
  - Integration times from 10us to 60s
- 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
  - 10 user programmable digital I/O
- Onboard Analog Interface
  - Analog Input: 13bit, 0-5V
  - Analog Output: 9bit, 0-5V
- EEPROM storage for
  - Wavelength Calibration Coefficients
  - Linearity Correction Coefficients
  - Absolute Irradiance Calibration (optional)
- Plug-n-Play Interface for PC applications
- 30-pin connector for interfacing to external products
- CE Certification

Specifications

Specifications	Criteria
Absolute Maximum Ratings: V_{CC} Voltage on any pin	 + 5.5 VDC Vcc
Physical Specifications: Physical Dimensions Weight	 148.6 mm x 104.8 mm x 45.1 mm 570 g
Power: Power requirement (master) Supply voltage Power-up time	 500 mA at +5 VDC 4.5 – 5.5 V ~5s depending on code size

Specifications	Criteria
Spectrometer:	
Design	Asymmetric crossed Czerny-Turner
Focal length (input)	F/4 101mm
Focal length (output)	68 mm (75, 83 and 90 mm focal lengths also available)
Input Fiber Connector	SMA 905 to single-strand optical fiber (0.22 NA)
Gratings	14 different gratings
Entrance Slit	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.)
Detector	Toshiba TCD1304AP
Filters	2nd & 3rd order rejection, long pass (optional)
Spectroscopic:	
Integration Time	10µs – >60sec
Dynamic Range	2500 single integration period, 2.5 x 10^9 over integration range
Signal-to-Noise	300:1 single acquisition
Readout Noise (single dark spectrum)	6 counts RMS, 20 counts peak-to-peak
Resolution	0.03 – 1.0 nm varies by configuration (see www.oceanoptics.com for configuration options)
Stray Light	<0.05% at 600 nm; <0.10% at 435 nm
Spectrometer Channels	One
Environmental Conditions:	
Temperature	-30° to +70° C Storage & -10° to +50° C Operation
Humidity	0% - 90% non-condensing
Interfaces:	
USB	USB 2.0, 480 Mbps
RS-232	2-wire RS-232
I^2C	**I**nter-**I**ntegrated **C**ircuit 2-Wire serial BUS
SPI	3-Wire

Mechanical Diagram

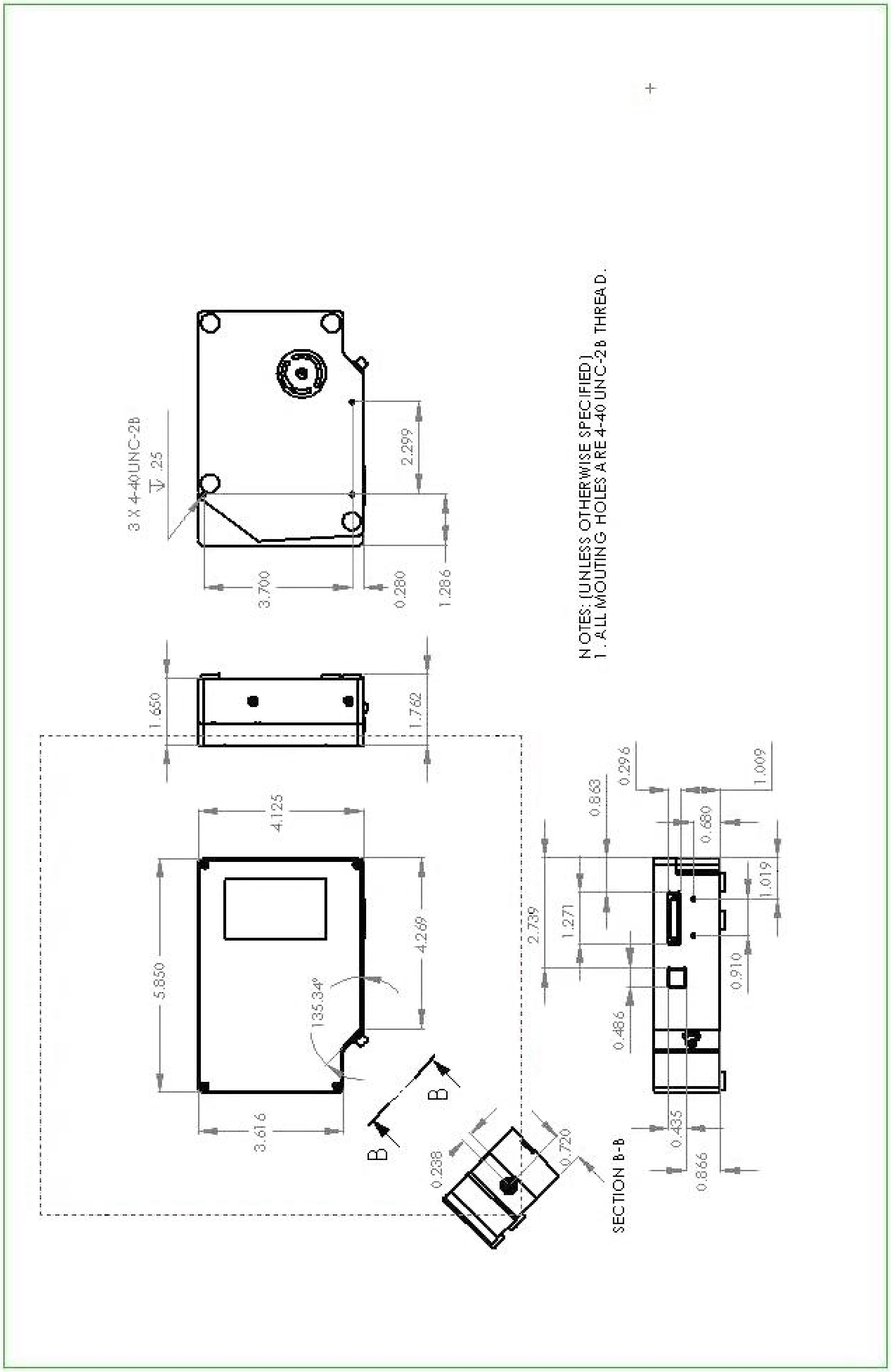
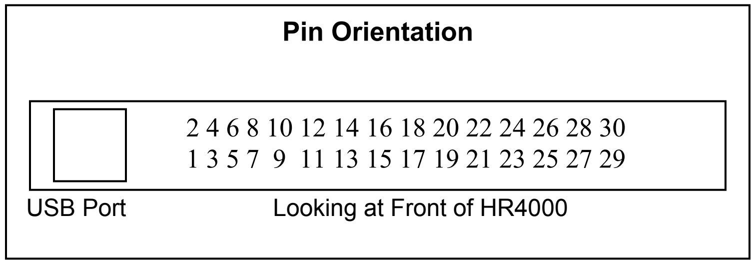


Figure 1. HR4000 Outer Dimensions

Electrical Pinout

Listed below is the pin description for the HR4000 Accessory Connector (J3) located on the front vertical wall of the unit. The connector is a Pak50$_{TM}$ model from 3M Corp. Headed Connector Part# P50-030P1-RR1-TG. Mates with Part # P50-030S-TGF (requires two: 1.27mm (50 mil) flat ribbon cable: Recommended 3M 3365 Series).

Pin#	Description
1	RS232 Rx
2	RS232 Tx
3	GPIO(2)
4	V5_SW
5	Ground
6	I2C SCL
7	GPIO(0)
8	I2C SDA
9	GPIO(1)
10	External Trigger In
11	GPIO(3)
12	VCC, VUSB or 5Vin
13	SPI data out
14	VCC, VUSB or 5Vin
15	SPI data in
16	GPIO(4)
17	Single Strobe
18	GPIO(5)
19	SPI Clock
20	Continuous Strobe
21	SPI Chip Select
22	GPIO(6)
23	Analog In (0-5V)
24	Analog Out (0-5V)
25	Lamp Enable
26	GPIO(7)
27	Ground
28	GPIO(8)
29	Ground
30	GPIO(9)



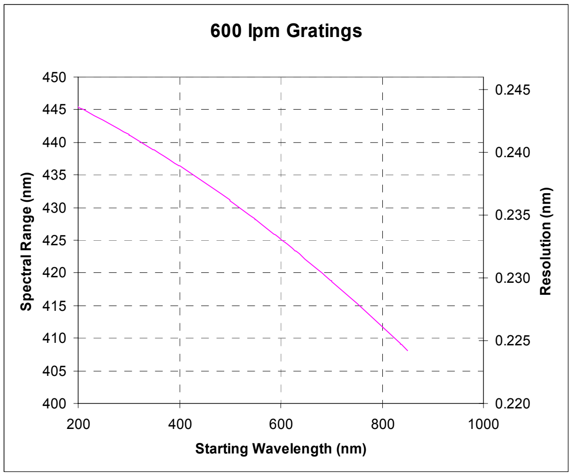
Pin #	Function	Input/Output	Description
1	RS232 Rx	Output	RS232 Receive signal – for communication with PC connect to DB9 pin 3
2	RS232 Tx	Input	RS232 Transmit signal – for communication with PC connect to DB9 pin 2
3	GPIO (2)	Input/Output	General purpose, software-programmable digital input/output (channel number)
4	V5_SW	Output	This is a regulated 5-Volt power pin out of the HR4000. It can supply 50mA (max).
5	Ground	Input/Output	Ground
6	I^2C SCL	Input/Output	The I2C Clock signal for communications to other I2C peripherals
7	GPIO (0)	Input/Output	General purpose, software-programmable digital input/output (channel number)
8	I^2C SDA	Input/Output	The I2C Data signal for communications to other I2C peripherals
9	GPIO (1)	Input/Output	General purpose, software-programmable digital input/output (channel number)
10	External Trigger In	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 this is a clock input, which defines the integration period of the spectrometer.
11	GPIO (3)	Input/Output	General purpose, software-programmable digital input/output (channel number)
12	V_{CC} , V_{USB} or $5V_{in}$	Input or Output	This is the input power pin to the HR4000. 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).
13	SPI data out	Output	The SPI Master Out Slave In (MOSI) signal for communications to other SPI peripherals
14	V_{CC} , V_{USB} or $5V_{in}$	Input or Output	This is the input power pin to the HR4000. 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).
15	SPI data in	Input	The SPI Master In Slave Out (MISO) signal for communications to other SPI peripherals
16	GPIO (4)	Input/Output	General purpose, software-programmable digital input/output (channel number)
17	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.
18	GPIO (5)	Input/Output	General purpose, software-programmable digital input/output (channel number)

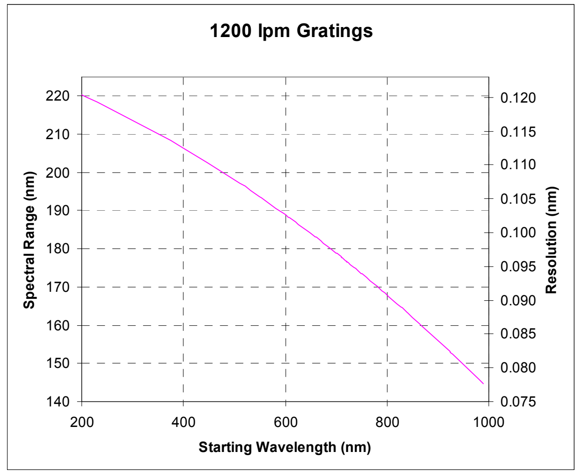
Pin Definition and Descriptions (Cont'd)

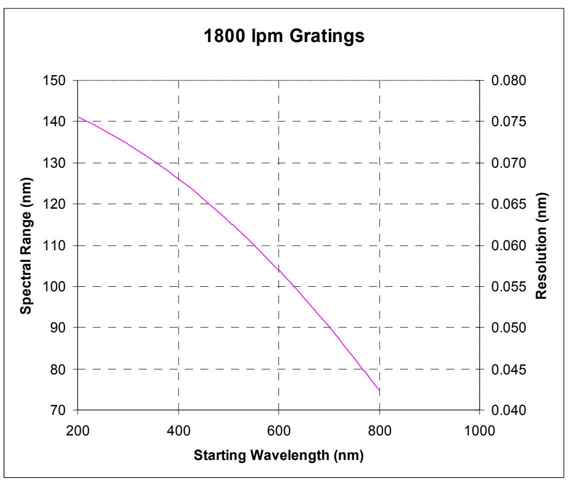
Pin #	Function	Input/Output	Description
19	SPI Clock	Output	The SPI Clock signal for communications to other SPI peripherals
20	Continuous Strobe	Output	TTL output signal used to pulse a strobe that is divided down from the Master Clock signal
21	SPI Chip Select	Output	The SPI Chip/Device Select signal for communications to other SPI peripherals
22	GPIO (6)	Input/Output	General purpose, software-programmable digital input/output (channel number)
23	Analog In (0-5V)	Input	The Analog In is a low power, 13-bit Analog to Digital input with a 0-5 Volt input range.
24	Analog Out (0-5V)	Output	The Analog Out is a 9-bit programmable output voltage with a 0-5 Volt range.
25	Lamp Enable	Output	A TTL signal that is driven Active HIGH when the Lamp Enable command is sent to the USB2000
26	GPIO (7)	Input/Output	General purpose, software-programmable digital input/output (channel number)
27	Ground	Input/Output	Ground
28	GPIO (8)	Input/Output	General purpose, software-programmable digital input/output (channel number)
29	Ground	Input/Output	Ground
30	GPIO (9)	Input/Output	General purpose, software-programmable digital input/output (channel number)

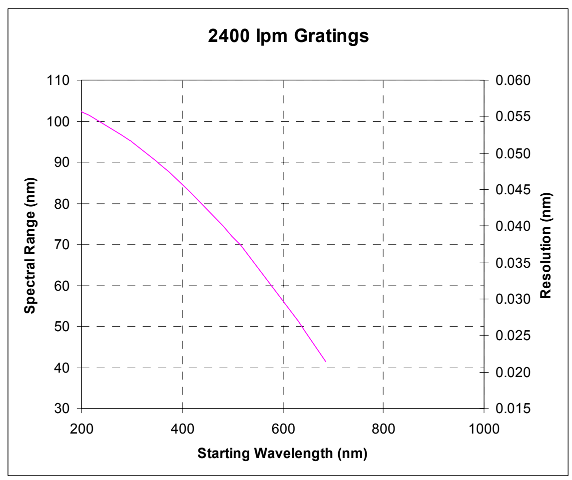
Optical Performance

Below are the graphs showing the range and resolution for the various gratings when configured with a 5um slit.









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 HR4000 warms up, the baseline signal will shift slowly downward a few counts depending on the external environment. The baseline signal is set between 90 and 140 counts 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 table is a description of all of the pixels:

Pixels	Description
1 – 5	Not usable
6 – 18	Optical black pixels
19 – 21	Transition pixels
22 – 3669	Optical active pixels
3670 – 3681	Not usable

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 ~12µs. 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 delay and pulse width. The pulse is only active if the Lamp Enable command is active. This pulse allows for synchronization of external devices to the spectrometers integration period. The Strobe delay can range from 0 to 30 ms and the pulse width can range from 1µs to the full 30ms.

Continuous Strobe

The Continuous Strobe signal is a programmable frequency pulse-train (50% duty cycle). The range of frequency is 100µs to 60s. The pulse 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. This synchronization only occurs when the integration period is a multiple of a power of 2.

Triggering Modes

The HR4000 supports four triggering modes, which are set with the Trigger Mode command. A detail of each triggering mode follows.

Normal

In this mode, the HR4000 uses the user-defined integration clock and continuously scans the CCD array.

External Software Trigger

In this mode, the HR4000 uses the user-defined integration clock; however, the A/D converter is required to wait until the Trigger Input Signal goes HIGH before it acquires the data at the start of the next integration period. This is an asynchronous trigger mode that allows the user to define an integration period through the software. The time between scans is dependent on PC speed.

External Hardware Trigger

In this mode, the HR4000 uses an external rising edge of a TTL signal to begin a single integration cycle. The integration time is input by the user into the software before the trigger occurs.

External Synchronization Trigger

In this mode of the HR4000, the integration clock is essentially input into the spectrometer. This allows the spectrometer to be synchronized with another device. The synchronized trigger must be a TTL signal with a frequency range of 5ms to 60s.

Analog Input & Output

Analog Input

The analog input option of the HR4000 is a dedicated 13-bit Analog to Digital converter, which has an input range of 0 to 5-Volts. The analog input is accessed through the HR4000's 30-pin accessory connector. The spectrometer provides a software-programmable Gain and D.C. offset adjustment for the input signal. The digitized output is passed into software and can be used for various applications such as temperature or pressure transducers.

Analog Output

The HR4000 provides a user programmable Analog output, which is accessed through its 30-pin accessory connector. This analog out is a 9-bit, low power, digital to analog converter with a range of 0-5 Volts. The analog output can be used for multiple applications such as single pixel intensity analysis or programmable reference/dimmer to light sources.

Digital Inputs & Outputs

General Purpose Inputs/Outputs (GPIO)

The HR4000 will have 10 user programmable digital Input/Output pins, which can be accessed at the 30-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.

The GPIO Input and Output levels are as follows:

VIL(min) = -0.5V
VIL(max) = 0.8V
VIH(min) = 2.0V
VIH(max) = 3.6V
VOL(max) = 0.4V
VOH(min) = 2.4V
IOL = 24mA
IOH = -24mA

GPIO Absolute Maximum Ratings are as follows:
VIN(min) = -0.5V
VIN(max) = 4.0V

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 HR4000 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 HR4000 to be a standalone device, which can output data to other logic devices/controllers such as a PLC or microcontroller. The HR4000 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.

HR4000 USB Port Interface Communications and Control Information

Overview

The HR4000 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 HR4000. Only experienced USB programmers should attempt to interface to the HR4000 via these methods.

Hardware Description

The HR4000 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 8K 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 2457. The HR4000 can have 2 Product ID's depending upon the EEPROM configuration. In the case where the code is loaded from the EEPROM the PID is 0x1012. The microcontroller allows for the code to be loaded from the host processor (Re-numeration), in this case the PID is 0x1011.

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 HR4000 through End Point 1 Out (EP1). All spectra data is acquired through End Point 2 and 6 In and all other queries are retrieved through End Point 1 In (EP1). The endpoints enabled and their order is:

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

USB Command Summary

EP2 Command Byte Value	Description	Version
0x01	Initialize HR4000	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^2C Read	0.90.0
0x61	General I^2C Write	0.90.0
0x62	General SPI I/O	0.90.0
0x68	PSOC Read	0.90.0
0x69	PSOC Write	0.90.0
0x6A	Write Register Information	0.90.0

EP2 Command Byte Value	Description	Version
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 HR4000 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 HR4000

Initializes certain parameters on the HR4000 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 HR4000 integration time in microseconds. The value is a 32-bit value whose acceptable range is 10 – 65,535,000us. 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-LSB

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

Set Strobe Enable Status

Sets the HR4000 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 = !0 ➔ Lamp Enable HIGH/On

Byte Format

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

Set Shutdown Mode

Sets the HR4000 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. The 20 configuration variables are indexed as follows:

Data Byte - 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 – HR4000 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	Data byte

Return Format (EP7)

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

Byte 0	Byte 1	Byte 2	Byte 3	…	Byte 17
0x05	Configuration Index	ASCII byte 0	ASCII byte 1	…	ASCII byte 15

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 17
0x06	Configuration Index	ASCII byte 0	ASCII byte 1	…	ASCII byte 15

Request Spectra

Initiates a spectra acquisition. The HR4000 will acquire a complete spectrum (3840 pixel values). The data is returned in bulk transfer mode through EP2 and EP6 depending on the USB Communication Speed. The table below provides the pixel orderint 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 HR4000.

USB High Speed (480Mbps) Packet Format

In this mode the first 2K worth of data is read from EP6In and the rest is read from EP2In. The packet format is described below.

Packet #	End Point	# Bytes	Pixels
0	EP6In	512	0-255
1	EP6In	512	256-511
2	EP6In	512	512-767
3	EP6In	512	768-1023
4	EP2In	512	1024-1279
5	EP2In	512	1280-1535
…	EP2In	512	
14	EP2In	512	3584–3840
15	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 2 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	
119	EP2In	64	3808–3839
120	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 120 – **Synchronization Packet (1 byte)**

Byte 0
0x69

Set Trigger Mode

Sets the HR4000 Trigger mode to one of three states. If an unacceptable value is passed then the trigger state is unchanged (Refer to the HR4000 manual for a description of the trigger modes).

Data Value = 0 ➔ Normal (Free running) Mode
Data Value = 1 ➔ Software Trigger Mode
Data Value = 2 ➔ External Synchronization Trigger Mode
Data Value = 3 ➔ External Hardware Trigger Mode

Byte Format

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

Query Number of Plug-in Accessories

Queries the number of Plug-in accessories preset. This is determined at power up and whenever the Plug-in Detect command is issued

Byte Format

Byte 0
0x0B

Return Format

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

Byte 0
Value (BYTE)

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^2Caddresses 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^2C bus. No data values are returned.

Byte Format

Byte 0
0x0D

General I^2C Read

Performs a general purpose read on the I^2C 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^2C 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^2C Address	Bytes to Read

Return Byte Format

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

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

General I²C Write

Performs a general-purpose write on the I²C 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 I²C 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. The SPI bus runs at ~25KHz 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 3	…	Byte N+1
# of Bytes (N)	Read Byte 0	Read Byte 1	Read Byte 2	…	Read Byte N

Write Register Information

Most all of the controllable parameters for the HR4000 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 MSB | LSB 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	Description	Default Value	Min Value	Max Value
0x00*	Set Master Clock Counter Divisor. Master Clock freq = 48MHz/Divisor	12	1	0xFFFF
0x04	FPGA Firmware Version (Read Only)			
0x08	Continuous Strobe Timer Interval	10 (100 Hz)	0	0xFFFF
0x0C	Continuous Strobe Base Clock. Divisor operates from 48MHz Clock	48000 (1KHz)	0	0xFFFF
0x10*	Integration Period Base Clock Base Freq = 48MHz	480 (10us)	0	0x0FFF
0x18*	Integration Clock Timer	600 (6ms)	0	0xFFFF
0x20*	Shutter Clock (contact OOI for info)	N/A	0	0x0FFF
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
0x2C&*	Trigger Mode 1 = External Synchronization 2 = External Hardware Trigger	0	0	2
0x30	Reserved			
0x38	Single Strobe High Clock Transition	1	0	0x0FFF
0x3C	Single Strobe Low Clock Transition	10	0	0x0FFF
0x40	Strobe Enable	0	0	0x0001
0x48	GPIO Mux Register (0 = pin is GPIO pin, 1 = pin is alternate function)	0	0	0x03FF
0x50	GPIO Output Enable (1 = pin is output, 0= pin is input)	0	0	0x03FF
0x54	GPIO Data Register For Ouput = Write value of signal For Input = Read current GPIO state	0	0	0x03FF
0x58	Reserved			

* - These values affect spectrometer performance and should not be changed. This information is included just for completeness.

& - These values are controlled by other command interfaces to the HR4000 (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 MSB	Value LSB

Read PCB Temperature

Read the Printed Circuit Board Temperature. The HR4000 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 used 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

Writes 60 bytes of data, which is used 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, which contains the current operating information. The structure of the status packet 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 !0 – 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 that have been loaded into End Point Memory
12	Reserved	
13	Reserved	
14	USB Communications Speed	0 – Full Speed (12Mbs) 0x80 – High Speed (480 Mpbs)
15	Reserved	