

# QE65000 Data Sheet

## Description

The Ocean Optics QE65000 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 QE65000 spectrometer is a unique combination of technologies providing users with both an unusually high spectral response and high optical resolution in a small footprint. The electronics have been designed for considerable flexibility in connecting to various modules as well as external interfaces. The QE65000 interfaces to PCs, PLCs and other embedded controllers through USB 2.0 or RS-232 communications. The information included in this data sheet provides detailed instructions on the connection and operation of the QE65000.

The detector used in the QE65000 spectrometer is a scientific-grade, back-thinned, TE Cooled (TEC), 1044x64 element CCD array from Hamamatsu (product number S7031-1006). For complete details on this detector, visit [www.Hamamatsu.com](http://www.Hamamatsu.com).

The QE65000 operates from power provided through the USB (without TEC operation), or from a separate + 5VDC power supply. The QE65000 is a microcontroller-controlled spectrometer, thus all operating parameters are implemented through software interfacing to the unit.

# Features

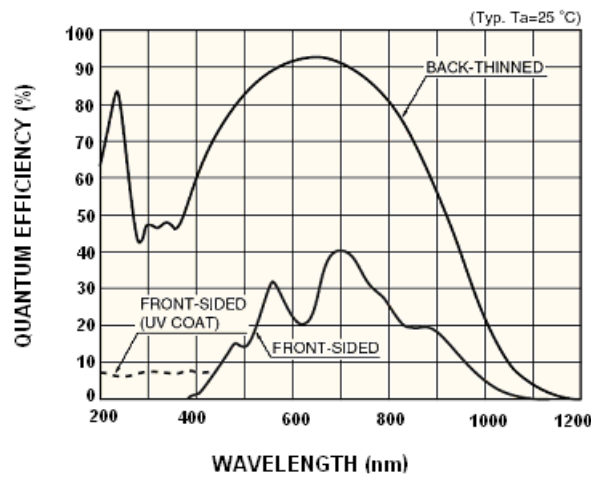
- ❑ Hamamatsu S7031-1006 Detector:
  - Peak QE: 90%
  - Back-thinned for good UV sensitivity
  - MPP operation for low noise operation
  - TE Cooled
- ❑ Spectrometer Design:
  - Symmetrical Crossed Czerny Turner
  - 101mm focal length
  - 14 gratings (H1 – H14)
  - 6 slit widths
- ❑ Electrical Performance:
  - 16 bit, 500KHz A/D Converter
  - Integration times from 8ms to ~10 minutes
- ❑ Embedded microcontroller allows programmatic control of all operating parameters and standalone operation:
  - USB 2.0 480Mbps (high-speed) and 12Mbps (full speed)
  - RS232 115Kbaud
  - Multiple Communication Standards for digital accessories (SPI, I2C)
- ❑ TE Cooler
  - Software-controlled set-point
  - Temperature stability: <math><0.1^{\circ}\text{C}</math>
  - Maximum cooling  $40^{\circ}\text{C}$  below ambient
- ❑ 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
- ❑ 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
Physical Specifications: Physical Dimensions (LxWxH) Spectrometer Weight Power Supply Weight	182 mm (7.17 in.) x 110 mm (4.33 in.) x 47 mm (1.85 in.) 1.15 kg (2.6 lbs.) 0.45 kg (1 lb.)
Power: Power requirement Supply voltage Power-up time GPIO Output Voltage	500 mA at +5 VDC (no TE Cooler) 3.5A at +5V (with TE Cooler) 4.5 – 5.5 V ~2s depending on code size 3.3 V
Absolute Maximum Ratings: V <sub>CC</sub> Voltage on any pin	+ 5.5 VDC V <sub>CC</sub>
Spectrometer: Design Focal length (input) Input Fiber Connector Gratings Entrance Slit Detector Pixels Pixel size Active area Spectral range Quantum efficiency Well Depth Dark Current Filters	Symmetric crossed Czerny-Turner F/4 101mm SMA 905 to single-strand optical fiber (0.22 NA) 14 different gratings (H1 – H14); HC1 grating 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.) Hamamatsu S7031-1006 1024 x 58 (total pixels 1044 x 64) 24.6μm square 24.576 x 1.392mm 200 – 1100nm with window (see etalon section). VUV option available (150nm). VUV option includes purge port & window removal (no TE Cooling) 90% peak (see figure following this table) Individual pixel: 300K electrons; Column summing well: ~1.5M electrons 4000 e/pixel/sec (typ) @ 25° C; 200 e/pixel/sec (typ) @ 0° C 6 OF Series available
Spectroscopic: Integration Time Dynamic Range Signal-to-Noise Dark Noise (single dark spectrum) Readout Noise Linearity	8ms – 15 minutes 40000:1 single integration period, 7.5 x 10 <sup>9</sup> over integration range 1000:1 single acquisition 3 counts RMS 1.5 counts RMS (40 electrons) ~1% max. nonlinearity (uncorrected); <0.5% nonlinearity (corrected)

**QE65000 Data Sheet**

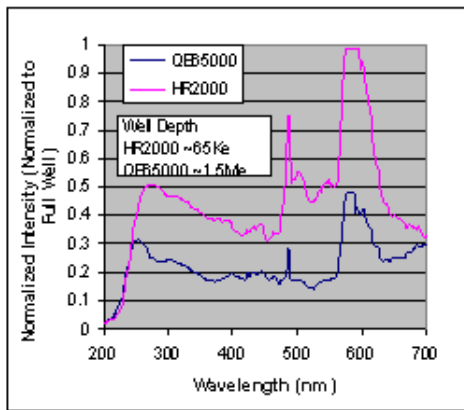
Specifications	Criteria
Environmental Conditions: Temperature TEC Control Temperature  Humidity	0 to 50°C 45 to 30°C below ambient temperature  0% – 90% noncondensing
Interfaces: USB RS-232	USB 2.0, 480 Mbps 3-wire RS-232



**Quantum Efficiency of Detector**

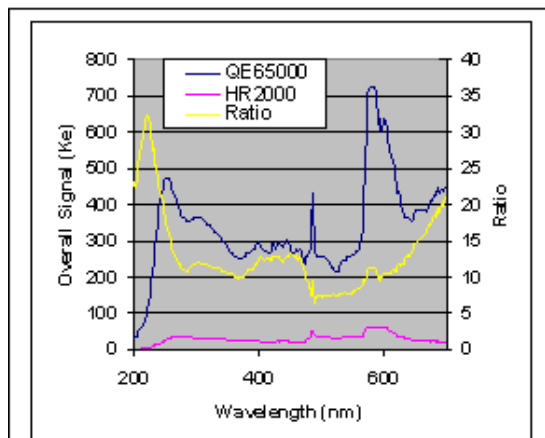
## QE65000 Sensitivity

The QE65000 contains a back-thinned detector that has up to 90% peak UV Quantum Efficiency (QE). The graph in the following figure shows the overall sensitivity of the HR2000 & QE65000 for the UV & Visible range. The raw scope mode signals are normalized to the full-scale saturation level under the same acquisition settings. From this data it may appear that the HR2000 has better sensitivity than the QE65000. However, it's important to factor in the well depth differences.



Normalized Scope mode comparison between QE65000 and HR2000. Spectra is of a DH2000 lamp taken at 5ms for the HR2000 and 10ms for the QE65000. This integration time difference has been factored into the data.

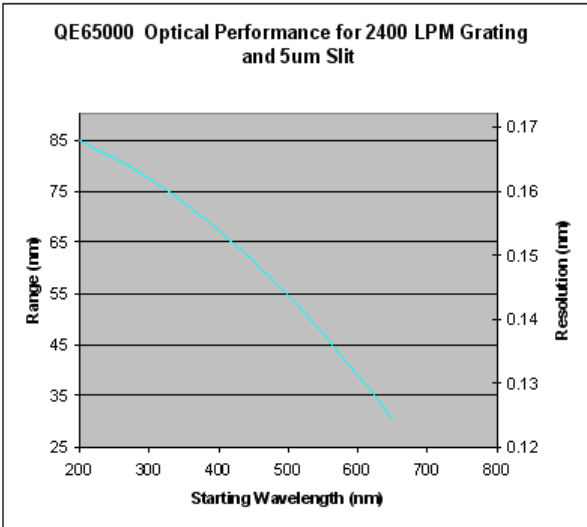
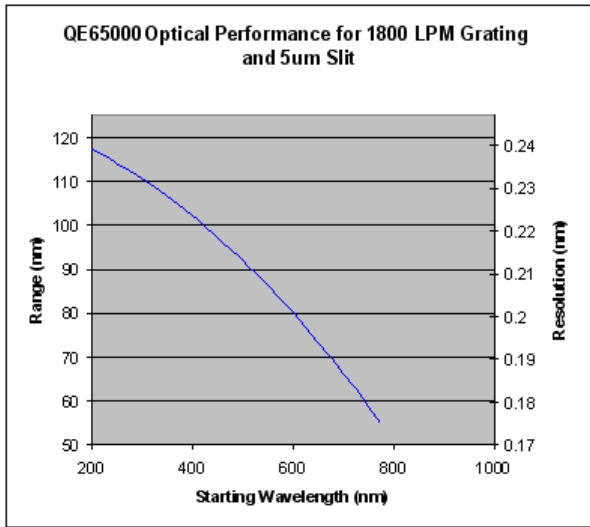
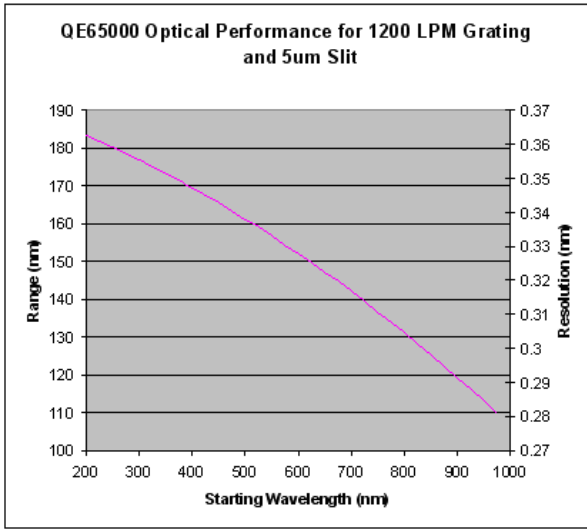
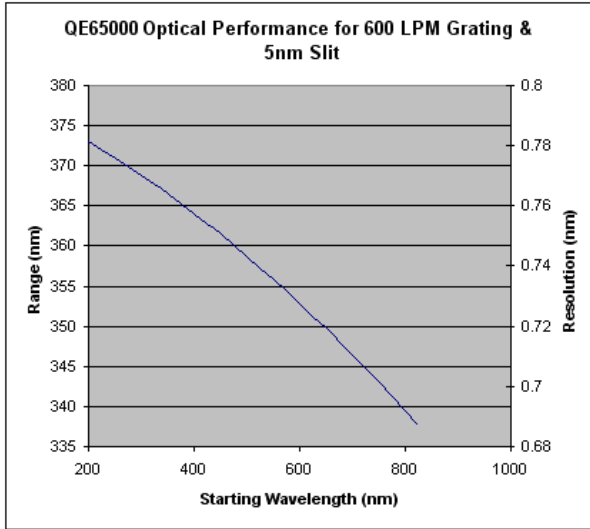
The graph below shows the total charge collected by the CCD in terms of electrons. While at first this may seem like a strange way to compare the overall sensitivity, it provides a good comparison between the two detectors. Basically the QE65000 has the good S/N of a deep well device but the sensitivity of a shallow well device. The sum total is a 10-30X increase in total signal collected.



Sensitivity comparison between QE65000 and HR2000 showing total signal collected. The QE65000 has good S/N and great sensitivity. The ratio of the two curves is plotted in yellow on the left axis.

# Optical Performance

Below are the graphs showing the range and resolution for the various gratings when configured with a 5 $\mu\text{m}$  slit.



The following table shows the resolution for various slit sizes.

		QE65000 Resolution (nm)					
		Slit					
		5	10	25	50	100	200
		Pixel Resolution Factor					
Grating	Avg Range	2	2.2	2.6	3.3	4.6	8.9
300	750	1.46	1.61	1.90	2.42	3.37	6.52
600	360	0.70	0.77	0.91	1.16	1.62	3.13
1200	150	0.29	0.32	0.38	0.48	0.67	1.30
1800	90	0.18	0.19	0.23	0.29	0.40	0.78
2400	70	0.14	0.15	0.18	0.23	0.31	0.61

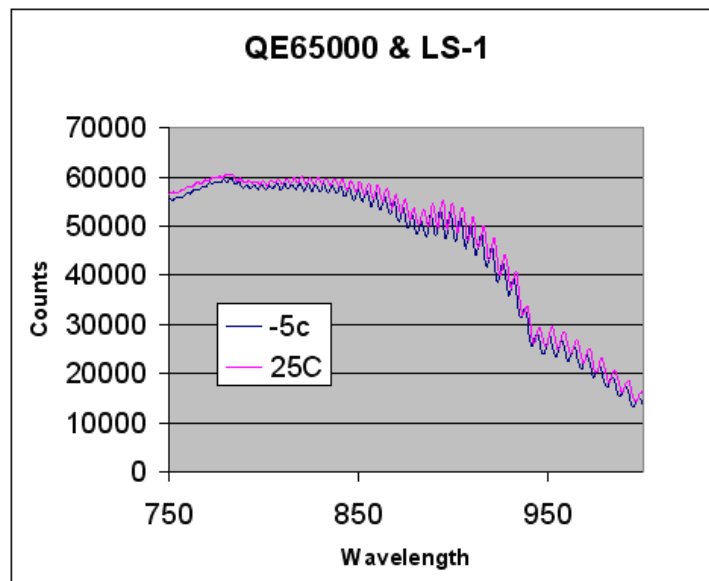
## QE65000 Etalon Effect

### Note

As of August 2010, the QE65000 began using a low-etalon detector, so the following information applies to units manufactured before that date.

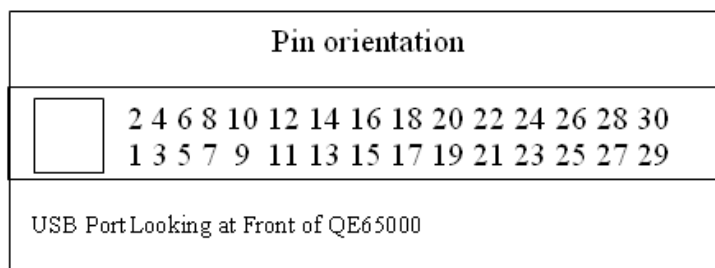
As with many detectors, the QE65000 has top layer passivations that create an etalon effect. This effect is most easily seen when broadband light is introduced into the optical bench as shown in the figure below. Due to tight process control at the detector manufacturer, the etalon effect occurs in the 800-1000nm range. This effect is stable and “normalizable” as long as the detector temperature is constant between the reference and sample spectra. To effectively eliminate this effect, the user must do the following:

- Run the TE Cooler to stabilize the detector temperature
- Use Absorbance, Transmission or Relative Irradiance modes in the software (not raw Scope mode)



# Electrical Pinout

Listed below is the pin description for the QE65000 Accessory Connector (J3) located on the front vertical wall of the unit. The connector is a Pak50™ 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 #	Function	Input/Output	Description
1	RS232 Rx	Input	RS232 receive signal – Communicates with a PC over DB9 Pin 3
2	RS232 Tx	Output	RS232 transmit signal – Communicates with a PC over DB9 Pin 2
3	GPIO (2)*	Input/Output	Reserved
4	N/A	N/A	Reserved
5	Ground	Input/Output	Ground
6	I2C SCL	Input/Output	I2C clock signal for communication to other I2C peripherals
7	GPIO (0)*	Input/Output	Base clock
8	I2C SDA	Input/Output	I2C data signal for communication to other I2C peripherals
9	GPIO (1)*	Input/Output	Master clock
10	Ext. Trigger In	Input	TTL input trigger signal
11	GPIO (3)*	Input/Output	Integration clock
12	VCC or 5VIN	Input or Output	Input power pin for QE65000 – When operating via USB, this pin can power other peripherals – Ensure that peripherals comply with USB specifications (no TEC power)
13	N/A	N/A	Reserved
14	VCC or 5VIN	Input or Output	Input power pin for QE65000 – When operating via USB, this pin can power other peripherals – Ensure that peripherals comply with USB specifications (no TEC power)
15	N/A	N/A	Reserved
16	GPIO (4)*	Input /Output	Reserved

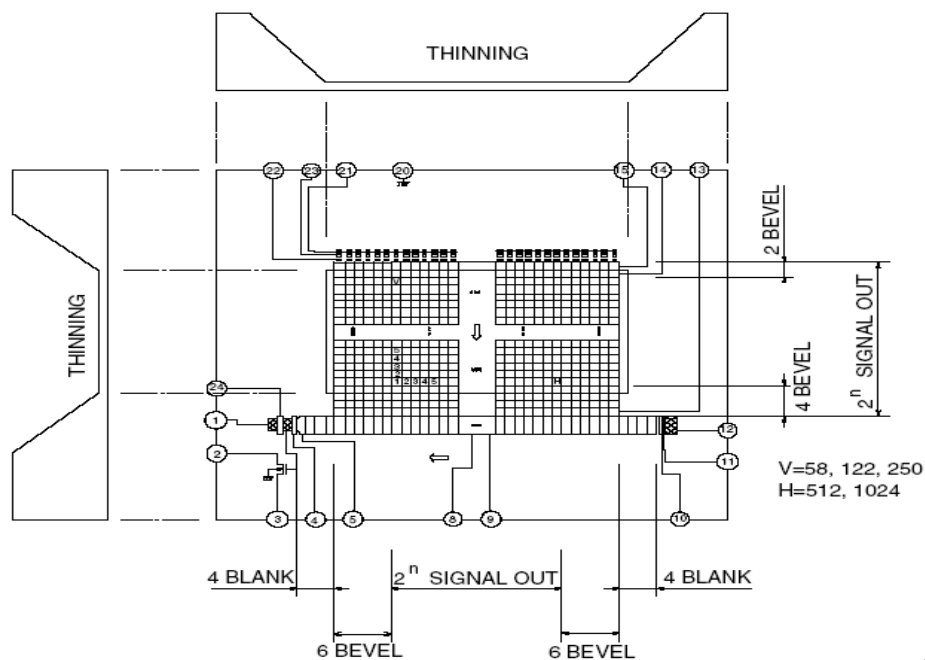
Pin #	Function	Input/Output	Description
17	Single Strobe	Output	TTL output pulse used as a strobe signal – Has a programmable delay relative to the beginning of the spectrometer integration period
18	GPIO (5)*	Input/Output	Acquire spectra (read enable)
19	N/A	N/A	Reserved
20	Continuous Strobe	Output	TTL output signal used to pulse a strobe – Divided down from the master clock signal
21	N/A	N/A	Reserved
22	GPIO (6)*	Input/Output	Reserved
23	N/A	N/A	Reserved
24	N/A	N/A	Reserved
25	Lamp Enable	Output	TTL signal driven Active HIGH when the Lamp Enable command is sent to the spectrometer
26	GPIO (7)*	Input/Output	Reserved
27	Ground	Input/Output	Ground
28	GPIO (8)*	Input/Output	A/D trigger
29	Ground	Input/Output	Ground
30	GPIO (9)*	Input/Output	EPFLAG
* GPIO works on FPGA firmware version 3.11.3 and FX2 firmware version 3.00.2 only.			



# QE65000 Pixel Definition

The QE65000 contains a Hamamatsu S7031-1006 CCD which is a two dimensional CCD. The QE65000 electronics only support reading out the device as a 1-D array (e.g. all rows are summed together on chip). The structure of the S7031 CCD is shown in figure 9. The device has 1024 x 58 active pixels and a total of 1044 x 64 pixels. While the pixels are digitized in the order shown in the diagram, they are rearranged depending on the interface (USB or RS232). The pixel order is shown below.

	USB Interface	RS232 Interface
Total Transmitted Values	1280 WORDS which contains 1044 pixels followed by 0's	1044 Values which contain 1044 pixel value
Pixel order	10 Blank & Bevel Pixels (first 10) 1024 Active Pixels 10 Blank & Bevel Pixels (last 10)	1024 Active Pixels 10 Blank & Bevel Pixels (last 10) 10 Blank & Bevel Pixels (first 10)
Notes: Order is rearranged by OOI drivers to be: 1024 Active Pixels 10 Blank & Bevel Pixels (last 10) 10 Blank & Bevel Pixels (first 10)		



**QE65000 CCD Device structure. The device has 58 active vertical pixels and 1024 active horizontal pixels.**

**Pixels on the Detector and Read Directly from Device**

Pixel	Description
0-3	Optical black
4-9	Not usable
10-1033	Optical active pixels
1034-1037	Not usable
1038-1043	Optical black

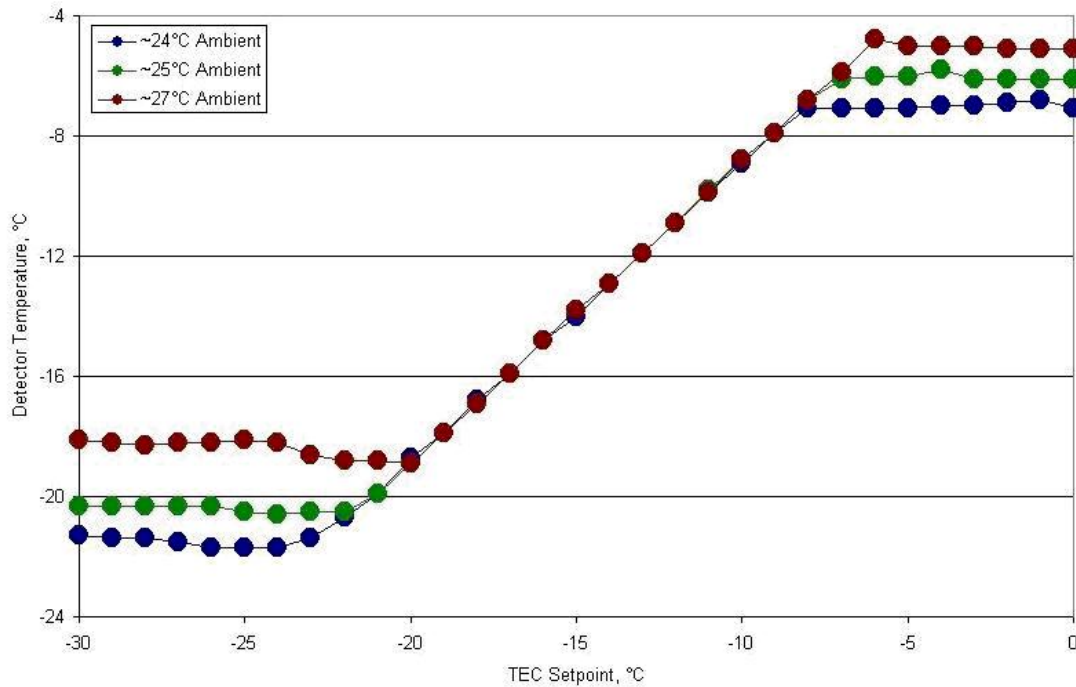
**Pixels Provided by Software**

Pixel	Description
0 - 1023	Optical active pixels
1024 - 1027	Optical black
1028 - 1033	Not usable
1034 - 1037	Optical black
1038 - 1043	Not usable

## QE65000 TEC Cooler

The Detector Temperature Setpoint (slot 17, offset 2/3) is useful for those situations where it is necessary to adjust the detector temperature. The QE cooler is able to maintain a maximum temperature differential of approximately 40°C (e.g., if ambient is 25°C, the detector can be held at a minimum temperature of approximately -15°C). If the setpoint temperature is below the maximum temperature differential, the detector temperature will change as the ambient temperature changes, which will increase detector noise. A typical control plot result is shown below. (Note that for this system, precise detector temperature control would be maintained for any detector setpoint temperature between -8°C and -20°C (even though the ambient temperature changed from +24°C to +27°C). When sending commands to the TEC, always wait 100ms between commands.

## QE TEC Temperature Control



**Detector Temperature as a Function of Setpoint**

## Setting the TEC Temperature

The system does not automatically set the correct detector temperature at power up (instead the system sets the detector temperature to  $-10^{\circ}\text{C}$ ).

Additionally, if USB power is applied prior to the TEC power, setting the TEC temperature will not be effective.

### ► Procedure

To set the TEC temperature, the following sequence is recommended:

1. Read TEC temperature (command 0x72).
2. Disable TEC (command 0x71).
3. Pause approximately 100 milliseconds.
4. Set TEC temperature (command 0x73).
5. Enable Fan (command 0x70).
6. Enable TEC (command 0x71).

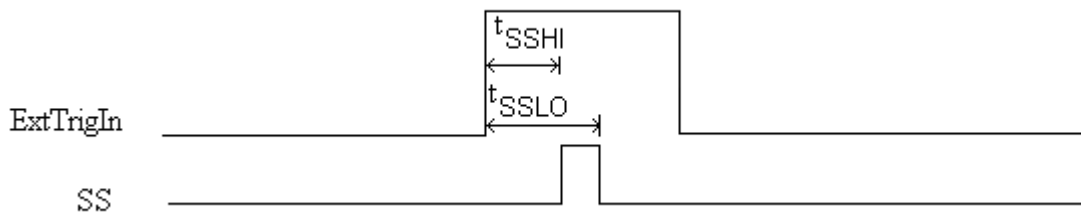
Wait approximately 2 seconds, and then read the TEC temperature. If the temperature hasn't responded as expected, repeat the sequence (up to 2 more times). If after a third try, the temperature still hasn't changed as expected, inform the user that TEC power is required to cool the detector. Note that if TEC power hasn't been applied, the detector temperature will increase above room temperature.

# Timing Signals

## Strobe Signals

### Single Strobe

The Single Strobe (SS) 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. In External Hardware Trigger mode, the timing of the Single Strobe is based on the External Trigger signal. In Normal (free running) and External Synchronization Trigger modes, the timing of the Single Strobe is based on the beginning of the integration period (the time between the starts of P1V vertical clock bursts). The timing diagram for the Single Strobe is shown below:



**Single Strobe**

The width and delay of the Single Strobe can be adjusted in 500ns increments. The 'SSHI is a programmable delay from trigger to the start of a single strobe. 'SSLO defines the width by setting the delay to clear the single strobe pulse from the trigger.

In Normal mode, the start of integration replaces the function of the external trigger signal.

### 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 2 $\mu$ s 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.

# QE65000 Trigger/Acquisition Modes

The QE65000 supports 4 Trigger/Acquisition modes including the standard free running mode. These modes are described below. Also refer to the External Triggering Options document for Spectrometer Firmware versions 3.0 and above located on our website at <http://www.oceanoptics.com/technical/External-Triggering2.pdf>. The following paragraphs describe these modes.

For firmware versions below 3.0, see <http://www.oceanoptics.com/technical/External-Triggering.pdf>.

- **Normal (Free-run) Mode:** In this mode, the spectrometer will acquire spectra 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 acquire another spectrum, even if one has not been requested. If a new spectrum request has come from the user, then this spectrum will be available to the user. If a new spectrum has not been requested by the user, then this spectrum will be saved to a FIFO (first in first out) buffer and another spectrum will be acquired. The QE65000 will store up to three spectra without a new request coming from the user. When the spectrometer receives a spectrum request and has data already in the buffer, the data returned to the user will be the oldest data set in the buffer. If a fourth spectrum is acquired before the first has been retrieved, then all three spectra will be deleted and the spectrometer will go into an idle mode waiting for a new spectrum request. While the spectrometer is in the idle mode, new spectra will not be acquired. When a new spectrum request comes from the user, a new data acquisition cycle and the buffering will start again.
- **Software Trigger Mode:** This mode is not supported by the QE65000.
- **External Synchronous Mode:** In this 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. As in normal mode, there is a three-spectrum buffer.
- **External Hardware Level Trigger Mode:** In this 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 stored in the FIFO 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 will occur, as in the Normal mode. The spectrometer will continue to behave as in the Normal mode until the trigger transitions to an active level.
- **External Hardware Edge Mode:** In this mode, a spectrum request has to be sent first, then the spectrometer will wait for a rising edge detected on the External Trigger input to start 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. Only one acquisition will be performed for each External Trigger pulse, no matter what the pulse's duration is, and the spectrometer will return to the idle state.

# QE65000 USB Port Interface Communications and Control Information

The QE65000 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 QE65000 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 QE65000. Only experienced USB programmers should attempt to interface to the QE65000 via these methods.

## Hardware Description

The QE65000 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<sup>2</sup>PROM that are loaded at boot-up via the I<sup>2</sup>C 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 Info

Ocean Optics Vendor ID number is 0x2457 and the Product ID is 0x1018.

## 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 QE65000 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	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

EP1 Command Byte Value	Description	Version
0x01	Initialize QE65000	0.90.0
0x02	Set Integration Time	0.90.0
0x03	Set Strobe Enable Status	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 <sup>2</sup> C Read	0.90.0
0x61	General I <sup>2</sup> C 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
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
0x70	Set Fan State	0.90.0
0x71	Set TEC Controller State	0.90.0
0x72	TEC Controller Read	0.90.0
0x73	TEC Controller Write	0.90.0
0xFE	Query Information	0.90.0

## USB Command Descriptions

A detailed description of all QE65000 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 QE65000

Description: Initializes certain parameters on the QE65000 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

Description: Sets the QE65000 integration time in milliseconds. The value is a 32-bit value whose acceptable range is 8 – 1,600,000ms (1600s or 26.67min). If the value is outside this range the value is unchanged. For integration times less than 655,000ms, the integration counter has a resolution of 1ms. For integration times greater than this the integration counter has a resolution of 25ms.

### 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

Description: Sets the QE65000 Lamp Enable line (J2 pin 25) 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
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## Byte Format

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

## Query Information

Description: 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 Index - Description
0 – Serial Number
1 – 0 <sup>th</sup> order Wavelength Calibration Coefficient
2 – 1 <sup>st</sup> order Wavelength Calibration Coefficient
3 – 2 <sup>nd</sup> order Wavelength Calibration Coefficient
4 – 3 <sup>rd</sup> order Wavelength Calibration Coefficient
5 – Stray light constant
6 – 0 <sup>th</sup> order non-linearity correction coefficient
7 – 1 <sup>st</sup> order non-linearity correction coefficient
8 – 2 <sup>nd</sup> order non-linearity correction coefficient
9 – 3 <sup>rd</sup> order non-linearity correction coefficient
10 – 4 <sup>th</sup> order non-linearity correction coefficient
11 – 5 <sup>th</sup> order non-linearity correction coefficient
12 – 6 <sup>th</sup> order non-linearity correction coefficient
13 – 7 <sup>th</sup> order non-linearity correction coefficient
14 – Polynomial order of non-linearity calibration
15 – Optical bench configuration info #1: gg fff sss gg – Grating #, fff – filter wavelength, sss – slit size
16 – QE65000 configuration info #2: Detector Serial Number
17 – TEC settings (at offsets 0-3): Offset 0: TEC enable (0 or 1) Offset 1: fan enable (0 or 1) Offset 2: detector set point temperature, celsius, times 10, low byte Offset 3: detector set point temperature, celsius, times 10, high byte Offset 4: <Future use> saturation intensity, low word, low byte (lowest order byte) Offset 5: <Future use> saturation intensity, low word, high byte Offset 6: <Future use> saturation intensity, high word, low byte Offset 7: <Future use> saturation intensity, high word, high byte (highest order byte)
18 – Power up Baud Rate Value
19 – User Defined

### 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

Description: 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

Description: Initiates a spectrum acquisition. The QE65000 will acquire a complete spectrum (1280 data values). The data is returned in bulk transfer mode through EP2. The table below provides the pixel order for the two 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. Bit 15 has to be flipped for every pixel before converting to an integer. There is an additional packet containing one value that is used as a flag to insure proper synchronization between the PC and QE65000.

## USB High Speed (480Mbps) Packet Format

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	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

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	
39	EP2In	64	1248-1279
20	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

Description: Sets the QE65000 Trigger mode to one of the following 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 Synchronous 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

## General I<sup>2</sup>C Read

Description: Performs a general purpose read on the I<sup>2</sup>C pins for interfacing to attached peripherals. The time to complete the command is determined by the amount of data transferred and response time of the peripheral. The I<sup>2</sup>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 <sup>2</sup> C Address	Bytes to Read

### Return Byte Format

Byte 0	Byte 1	Byte 2	Byte 3	...	Byte N+3
I <sup>2</sup> C Results	I <sup>2</sup> C Address	Bytes to Read	Data Byte 0	...	Data byte N

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

## General I<sup>2</sup>C Write

Description: Performs a general purpose write on the I<sup>2</sup>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<sup>2</sup>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	I <sup>2</sup> C Address	Bytes to Write	Data Byte 0	...	Data byte N

### Return Byte Format

Byte 0
I <sup>2</sup> C Results

## General SPI Input/Output

Description: 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

## Set TEC Controller State

Enables/Disables the detector's TEC controller.

Data Byte = 0 → TEC Controller Disabled  
 Data Byte = !0 → TEC Controller Enabled

**Enable Command Byte Format**

Byte 0	Byte 1	Byte 2
0x71	0x01	0x00

**Disable Command Byte Format**

Byte 0	Byte 1	Byte 2
0x71	0x00	0x00

## Set Fan State

Enables/Disables the fan inside the QE65000. The fan should run all of the time to insure proper cooling of the electronics and heat sink.

Data Byte = 0 → Fan Off  
 Data Byte = !0 → Fan On

**Enable Command Byte Format**

Byte 0	Byte 1	Byte 2
0x70	0x01	0x00

**Disable Command Byte Format**

Byte 0	Byte 1	Byte 2
0x70	0x00	0x00

## TEC Controller Write

Performs a write command to the TE controller. This command is used to set the detectors TEC set point temperature. The set-point value is a signed 16-bit value that is expressed in tenths of a degree Celsius. For example to set the temperature to  $-5.0^{\circ}\text{C}$  a value of  $-50$  or  $0\text{xFFCD}$  is sent.

### Byte Format Set Point LSB

Byte 0	Byte 1	Byte 2
0x73	Set-point LSB	Set-point MSB

## TEC Controller Read

Returns the detector temperature. The TE controller variables are only updated every 2 seconds, thus the calling program should not perform reads more often than this. This command is sent to EP1 and a total of 2 bytes data is retrieved through End Point 1 In. Format the LSB MSB into one word.

### Byte Format

Byte 0
0x72

### Return Format

Byte 0	Byte 1
Temp LSB	Temp MSB

The Detector Temperature is 16-bit signed value representing tenths of a degree Celsius as described in the TEC Controller Write command.

## Write Register Information

Description: Most all of the controllable parameters for the QE65000 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

**QE65000 Data Sheet**

Register Address	Description	Default Value	Min Value	Max Value	Time Base
0x00*	Master Clock Counter Divisor	6	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
0x10*	Integration Period Base Clock Divisor	1000	0	0xFFFF	1MHz
0x14	Set base_clk or base_clkx2 0: base_clk 1: base_clkx2	1	0	1	N/A
0x18*	Integration Clock Timer Divisor	10	0	0xFFFF	Integration Period Base Clock (see Register 0x10)
0x20*	Reserved				
0x28	Reserved				
0x2C&*	Reserved				
0x30	Reserved				
0x38	Single Strobe High Clock Transition Delay Count	1	0	0xFFFF	1MHz
0x3C	Single Strobe Low Clock Transition Delay Count	5	0	0xFFFF	1MHz
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 Output: Write value of signal For Input: Read current GPIO state	0	0	0x03FF	N/A
0x58	Reserved				

Notes: \* - Do not change these values because spectrometer performance can be affected.

& - Values are controlled by other command interfaces to QE65000 (Set integration time command).

## Read Register Information

Description: 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/Read Heatsink Temperature

Description: Read the Printed Circuit Board Temperature and the heat sink temperature. The QE65000 contains two DS1721 temperature sensor chips—one of which is mounted to the main PCB and the other which is mounted close to the heat sink. This command is sent to End Point 1 Out and the data is retrieved through End Point 1 In. The values returned are two signed 16-bit A/D conversion value which is equated to temperature by:

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

### Byte Format

Byte 0
0x6C

### Return Format (EP1In)

Byte 0	Byte 1	Byte 2
Read Result for PCB Temperature	ADC Value LSB	ADC Value MSB
Byte 3	Byte 4	Byte 5
Read Result for Heatsink Temperature	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

Description: 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

Description: 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

Description: 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 Spectral Data Values – WORD(s)	LSB   MSB order
2-5	Integration Time - WORD	Integration time in $\mu$ s – 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	For internal use
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 (12Mbps) 0x80 – High Speed (480 Mbps)
15	Reserved	

## Appendix A:

# QE65000 Serial Port Interface Communications and Control Information

## Overview

The QE65000 is a microcontroller-based miniature fiber optic spectrometer, which can communicate via the Universal Serial Bus or RS-232. This document contains the necessary command information for controlling the QE65000 via the RS-232 interface.

## Hardware Description

The QE65000 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 EEPROM, which are loaded at boot-up via the I<sup>2</sup>C bus.

## Instruction Set

### Command Syntax

The list of the commands is 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 QE65000 “echoes” the command back out the RS-232 port. In ASCII data mode the device transmits a prompt “>” to show that is waiting for a command. 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.

## Command Summary

Letter	Description	Version
A	Adds scans	2.00.0
B	Set Pixel Boxcar	2.00.0
C	Tec ON/OFF	2.00.0
D	Tec Setpoint	2.00.0
E		
F		
G	Set Data Compression	2.00.0
H		
I	Sets integration time(16-bit resolution)	2.00.0
J	Sets Lamp Enable Line	2.00.0
K	Changes baud rate	2.00.0
L	Clear Memory	
M		
N		
O		
P	Partial Pixel Mode	2.00.0
Q	Initialize Spectrometer	
R	Display Tec Current Temperature	2.00.0
S	Starts spectral acquisition with previously set parameters	2.00.0
T	Sets trigger mode	2.00.0
U		
V		
W	Write to FPGA Register	2.00.0
X		
Y		
Z		
a	Set ASCII mode for data values	2.00.0
b	Set binary mode for data values	2.00.0
i	Set integration time(32-bit resolution)	2.00.0
k	Sets Checksum mode	2.00.0
v	Provides microcode version #	2.00.0

Letter	Description	Version
x	Sets calibration coefficients	2.00.0
t	Reads the Board's temperature Degrees C	2.00.0
?	Queries parameter values	2.00.0

## Command Descriptions

A detailed description of all QE65000 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

Description: Sets the number of discrete spectra to be summed together.

Command Syntax:	A{DATA WORD}
Response:	ACK or NAK
Range:	1-65000
Default value:	1
Response:	ACK or NAK

### Pixel Boxcar Width

Description: 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  $\sim 3$  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
Response:	ACK or NAK

### Turn TEC Cooler ON/OFF

Turns TEC on or off. If turned on, the TEC is driven to the set point value.

Command Syntax:	C{DATA WORD}
Response:	ACK or NAK
Range:	0-1
Default value:	1
Response:	ACK or NAK

## TEC Cooler Temperature Setpoint Degrees C°

Sets the TEC cooler temperature. The value passed is the temperature in tenths of a degree C.

Command Syntax:	D{DATA WORD}
Response:	ACK or NAK
Range:	-50 to -250* (Format is X10 e.g., -10°C = -100)
Default value:	-100 (-10°C)
Response:	ACK or NAK
* Typical control range for 22 °C ambient is -7 to -20 °C	

## Set Data Compression

Description: Specifies whether the data transmitted from the QE65000 should be compressed to speed data transfer rates. For more information on QE65000 Data Compression, see Technical Note 1.

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

## Integration Time

Description: Sets the QE65000's integration time, in milliseconds, to the value specified. This command is limited to a 16 bit value. If a larger integration time is required, utilize the 32 bit version (lower case i command)

Command Syntax:	I{16 bit DATA WORD}
Response:	ACK or NAK
Range:	10 – 65,535
Default value:	10

## Integration Time(32-Bit)

Same as above command(I) but uses 32-bit values.

Command Syntax:	i{DATA DWORD}
Value:	10 - 1600000000
Response:	ACK or NAK
Default value:	10

## Lamp Enable

Description: Sets the QE65000'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

Description: Sets the QE65000'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 7=230,400
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

---

### Notes

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

The power-up Baud rate can be set by setting the EEPROM Memory slot to the desired value (i.e., 6 for a value of 115,200 Baud)

---

## Pixel Mode

Description: 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 1024 pixels 1 = every n <sup>th</sup> 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 1023 (denoted p1, p2, ... p10)	Example P 0 (spaces for clarity only) P 1<Enter> N<Enter> P 2<Enter> N<Enter > 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	

### Note

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.

## Read TEC Cooler Temperature in Degrees C°

Description: Returns the current temperature of the TEC Cooler.

Command Syntax:	R
Response:	{DATA WORD} followed by ACK
Default value	If stable then should reflect Setpoint. If not repeated R commands will show progression to setpoint temperature.

## Spectral Acquisition

Description: 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 16Bit or 32Bit Flag. If 1 then DWORDS transmitted for spectral data values
- WORD Add Scans
- DWORD integration time in Milliseconds
- WORD ALWAYS 0
- WORD pixel mode
- WORDS if pixel mode not 0, indicates parameters passed to the Pixel Mode command (P)
- WORDS/DWORDS spectral data
- WORD 0xFFFD – end of spectrum

## Trigger Mode

Description: Sets the QE65000's external trigger mode to the value specified.

Trigger Mode 4: This mode is called "Quasi-Real Time Acquisition" mode. In this mode we run the integration clock at a quick rate (150ms in the case of the QE65000). Once an acquisition is requested by the controller, the hardware waits until the current integration period expires and changes it to the desired rate which is typically much longer (i.e., many seconds). Once this integration period has expired, the integration time is changed back to the default rate and the detector is readout. In this mode, no external signal is required.

Command Syntax:	T{DATA WORD}
Value:	0 = Normal – Continuously scanning 1 = External Hardware Level Trigger Mode 2 = External Synchronous Trigger Mode 3 = External Hardware Edge Trigger Mode
Response:	ACK or NAK
Default value:	0

## Write FPGA Register

Description: Writes a value to an FPGA Register. The register map is defined in the USB command set section.

Command Syntax:	W{Register Address: WORD}{Register Value: WORD}
Value:	
Response:	ACK or NAK
Default value	N/A

---

### Note

To query a register value, issue ?W{Register Address}.

---

## ASCII Data Mode

Description: 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 QE65000 “echos” the command and data values back out the RS-232 port.

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

---

### Notes

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 QE65000 is in the ASCII data mode.

---

## Binary Data Mode

Description: 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

---

### Note

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

Description: Specifies whether the QE65000 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

Description: 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

## Read Board Temperature

Returns the PCB temperature followed by the heatsink temperature in Degrees 100<sup>th</sup>s C. Response will x100 e.g. 25C = 2500

Command Syntax:	t
Value:	None
Response:	{DATA WORD}{DATA WORD} followed by ACK
Default value:	N/A

## Calibration Constants

Description: 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 – 0 <sup>th</sup> order Wavelength Calibration Coefficient 2 – 1 <sup>st</sup> order Wavelength Calibration Coefficient 3 – 2 <sup>nd</sup> order Wavelength Calibration Coefficient 4 – 3 <sup>rd</sup> order Wavelength Calibration Coefficient 5 – Stray light constant 6 – 0 <sup>th</sup> order non-linearity correction coefficient 7 – 1 <sup>st</sup> order non-linearity correction coefficient 8 – 2 <sup>nd</sup> order non-linearity correction coefficient 9 – 3 <sup>rd</sup> order non-linearity correction coefficient 10 – 4 <sup>th</sup> order non-linearity correction coefficient 11 – 5 <sup>th</sup> order non-linearity correction coefficient 12 – 6 <sup>th</sup> order non-linearity correction coefficient 13 – 7 <sup>th</sup> 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 – QE65000 configuration: AWL V A – Array coating Mfg, W – Array wavelength (VIS, UV, OFLV), L – L2 lens installed, V – CPLD Version 17 – Reserved 18 – Startup Baud Rate value 19 – Reserved
Response:	ACK or NAK
Default value:	N/A

### Note

To query the constants, use the ?x{DATA WORD} format to specify the desired constant. To query all coefficients issue ?x-1 command.

## Query Variable

Description: 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 be 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.

The desired operating conditions are: acquire every 4<sup>th</sup> pixel from the spectrometer with a 200ms 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)
A2<CR>    (Add 5 spectra)
I200<CR>  (Set integration time to 200ms)
P1<CR>    (Pixel Mode 1...
4<CR>     every 4 pixels)
> S       (Acquire spectra)
...        Repeat as necessary
  
```

---

## Application Tips

- During the software development phase of a project, the operating parameters of the QE65000 may become out-of-synch with the controlling program. It is good practice to cycle power on the QE65000 when errors occur.
- If you question the state of the QE65000, you can transmit a space (or another non-command) using a terminal emulator. If you receive a NAK, the QE65000 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:
  7. Select **File | Properties**.
  8. Under Connect using, select Direct to Com x.
  9. Click Configure and match the following Port Settings:
    - Bits per second (Baud rate): Set to desired rate
    - Data bits: 8
    - Parity: None
    - Stop bits: 1
    - Flow control: NoneClick **OK** in **Port Settings** and in **Properties** dialog boxes.

# Technical Note 1: QE65000 Data Compression

Transmission of spectral data over the serial port is a relatively slow process. Even at 115,200 baud, the transmission of a complete 3840 point spectrum takes around 600 msec. The QE65000 implements a data compression routine that minimizes the amount of data that needs to be transferred over the RS-232 connection. Using the “G” command (Compressed Mode) and passing it a parameter of 1 enables the data compression. Every scan transmitted by the QE65000 will then be compressed. The compression algorithm is as follows:

1. The first pixel (a 16-bit unsigned integer) is always transmitted uncompressed.
2. The next byte is compared to 0x80.
3. If the byte is equal to 0x80, the next two bytes are taken as the pixel value (16-bit **unsigned** integer).
4. If the byte is not equal to 0x80, the value of this byte is taken as the difference in intensity from the previous pixel. This difference is interpreted as an 8-bit **signed** integer.
5. Repeat step 2 until all pixels have been read.

Using this data compression algorithm greatly increases the data transfer speed of the QE65000. Compression rates of 35-48% can easily be achieved with this algorithm.

The following shows a section of a spectral line source spectrum and the results of the data compression algorithm.

Pixel Value	Value Difference	Transmitted Bytes
185	0	0x80 0x00 0xB9
2151	1966	0x80 0x08 0x67
836	-1315	0x80 0x03 0x44
453	-383	0x80 0x01 0xC5
210	-243	0x80 0x00 0xD2
118	-92	0xA4
90	-28	0xE4
89	-1	0xFF
87	-2	0xFE
89	2	0x02
86	-3	0xFD
88	2	0x02
98	10	0x0A
121	23	0x17

Pixel Value	Value Difference	Transmitted Bytes
383	262	0x80 0x01 0x7F
1162	779	0x80 0x04 0x8A
634	-528	0x80 0x02 0x7A
356	-278	0x80 0x01 0x64
211	-145	0x80 0x00 0xD3
132	-79	0xB1
88	-44	0xD4
83	-5	0xFB
86	3	0x03
82	-4	0xFC
91	9	0x09
92	1	0x01
81	-11	0xF5
80	-1	0xFF
84	4	0x04
84	0	0x00
85	1	0x01
83	-2	0xFE
80	-3	0xFD
80	0	0x00
88	8	0x08
94	6	0x06
90	-4	0xFC
103	13	0x0D
111	8	0x08
138	27	0x1B

In this example, spectral data for 40 pixels is transmitted using only 60 bytes. If the same data set were transmitted using uncompressed data, it would require 80 bytes.

## Technical Note 2: QE65000 Checksum Calculation

For all uncompressed pixel modes, the checksum is simply the unsigned 16-bit sum (ignoring overflows) of all transmitted spectral points. For example, if the following 10 pixels are transferred, the calculation of the checksum would be as follows:

Pixel Number	Data (decimal)	Data (hex)
0	15	0x000F
1	23	0x0017
2	46	0x002E
3	98	0x0062
4	231	0x00E7
5	509	0x01FD
6	1023	0x03FF
7	2432	0x0980
8	3245	0x0CAD
9	1984	0x07C0

**Checksum value: 0x2586**

When using a data compression mode, the checksum becomes a bit more complicated. A compressed pixel is treated as a 16-bit **unsigned** integer, with the most significant byte set to 0. Using the same data set used in Technical Note 1, the following shows a section of a spectral line source spectrum and the results of the data compression algorithm.

Data Value	Value Difference	Transmitted Bytes	Value added to Checksum
185	0	0x80 0x00 0xB9	0x0139
2151	1966	0x80 0x08 0x67	0x08E7
836	-1315	0x80 0x03 0x44	0x03C4
453	-383	0x80 0x01 0xC5	0x0245
210	-243	0x80 0x00 0xD2	0x0152
118	-92	0xA4	0x00A4
90	-28	0xE4	0x00E4
89	-1	0xFF	0x00FF

Data Value	Value Difference	Transmitted Bytes	Value added to Checksum
87	-2	0xFE	0x00FE
89	2	0x02	0x0002
86	-3	0xFD	0x00FD
88	2	0x02	0x0002
98	10	0x0A	0x000A
121	23	0x17	0x0017
383	262	0x80 0x01 0x7F	0x01FF
1162	779	0x80 0x04 0x8A	0x050A
634	-528	0x80 0x02 0x7A	0x02FA
356	-278	0x80 0x01 0x64	0x01E4
211	-145	0x80 0x00 0xD3	0x0153
132	-79	0xB1	0x00B1
88	-44	0xD4	0x00D4
83	-5	0xFB	0x00FB
86	3	0x03	0x0003
82	-4	0xFC	0x00FC
91	9	0x09	0x0009
92	1	0x01	0x0001
81	-11	0xF5	0x00F5
80	-1	0xFF	0x00FF
84	4	0x04	0x0004
84	0	0x00	0x0000
85	1	0x01	0x0001
83	-2	0xFE	0x00FE
80	-3	0xFD	0x00FD
80	0	0x00	0x0000
88	8	0x08	0x0008
94	6	0x06	0x0006
90	-4	0xFC	0x00FC
103	13	0x0D	0x000D
111	8	0x08	0x0008
138	27	0x1B	0x001B

The checksum value is simply the sum of all entries in the last column, and evaluates to 0x2C13.

# Known Issues

Issues for the QE65000 include the following:

- Due to the architecture of the detector used on the QE65000, it may be necessary to set the **Single Strobe Timing** setting in SpectraSuite to 1500 counts (.7500 msec) to see a full value spectrum in this mode. Any value less than this will result in an attenuated value spectrum.
- The TEC may fail to turn on if you plug in the USB cable before TEC power cable. Ensure that the TEC power is always applied (TEC is enabled via SpectraSuite software) prior to USB power. When you first enable the TEC, wait a second before reading the temperature. If the TEC temperature is not decreasing, disable the TEC in software, wait a second and again enable the TEC. This ensures that the TEC always turns on.
- The TEC temperature control can be lost after reading the temperature several hundred or several thousand times (and as a result the temperature will no longer be updated correctly). The TEC temperature is still controlled at the last setpoint under these conditions, but to fix the problem you must unplug both the USB and TEC power for 15 seconds before repowering the device.
- TEC Temperature continuous display update causes the scan to pause and can crash the system if the integration time is changed rapidly (e.g., scrolling with up/down arrows).
- Reading the TEC during an acquisition is not recommended. Doing so can cause timing delays, resulting in a change in baseline.