

QE65 Pro Data Sheet

Description

The Ocean Optics QE65 Pro Spectrometer provides enhanced response in the UV and shortwave NIR regions over its predecessor, the QE65000, to offer unmatched performance for low-light level applications such as fluorescence, Raman analysis and DNA sequencing. The QE65 Pro 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 QE65 Pro 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 QE65 Pro 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 QE65 Pro.

The detector used in the QE65 Pro 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.

The QE65 Pro operates from power provided through the USB (without TEC operation), or from a separate + 5VDC power supply. The QE65 Pro is a microcontroller-controlled spectrometer, thus all operating parameters are implemented through software interfacing to the unit.

Features

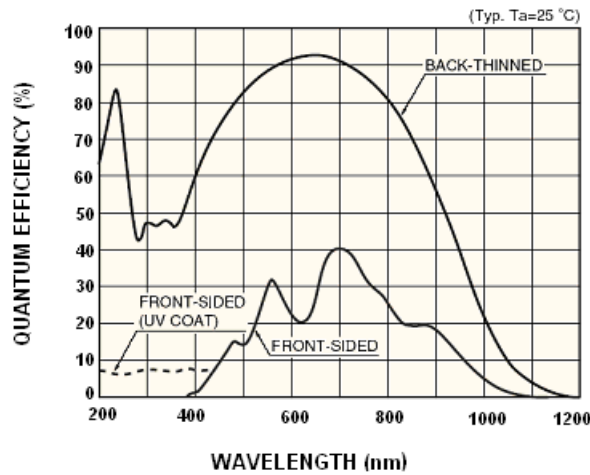
- ❑ Hamamatsu S7031-1006 Detector:
 - Peak QE: 90%
 - Back-thinned for good UV sensitivity
 - MPP operation for low noise operation
 - TE Cooled
- ❑ Spectrometer Design:
 - Symmetrical Crossed Czerny Turner
 - 101mm focal length
 - 14 gratings across UV-NIR; HC-1 composite grating for broad wavelength coverage
 - 6 slit widths
- ❑ Electrical Performance:
 - 16 bit, 500KHz A/D Converter
 - Integration times from 8ms to ~15 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°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

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 _{CC} Voltage on any pin | + 5.5 VDC V _{CC} |
| 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 (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 ⁹ over integration range 1000:1 single acquisition 3 counts RMS 1.5 counts RMS (40 electrons) ~1% max. nonlinearity (uncorrected); <0.5% nonlinearity (corrected) |

QE65 Pro Data Sheet

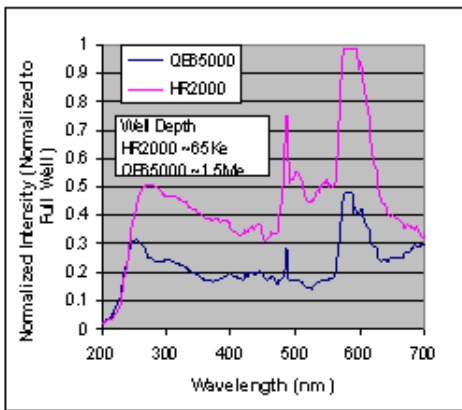
| Specifications | Criteria |
|---|---|
| Environmental Conditions: Temperature TEC Control Temperature | 0 to 50°C 45 to 30°C below ambient temperature |
| Humidity | 0% – 90% noncondensing |
| Interfaces: USB RS-232 | USB 2.0, 480 Mbps 3-wire RS-232 |



Quantum Efficiency of Detector

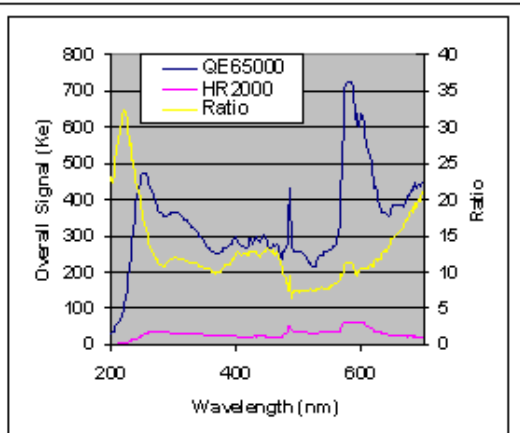
QE65 Pro Sensitivity

The QEPro 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 & QE65 Pro 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 QE65 Pro. 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.

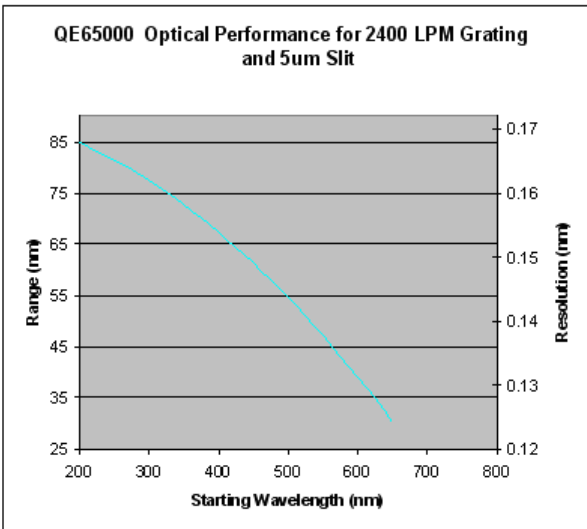
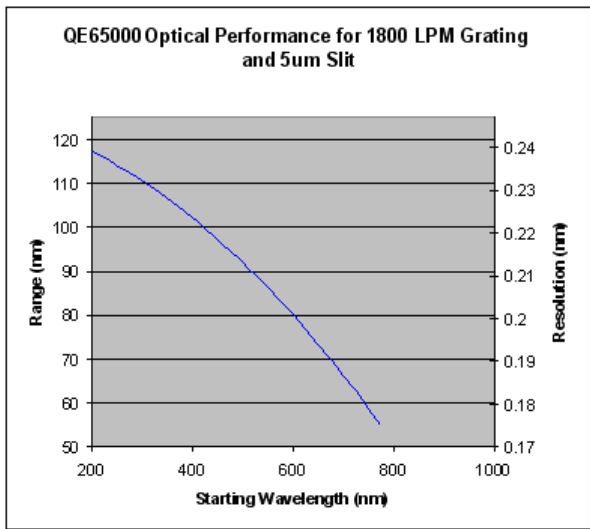
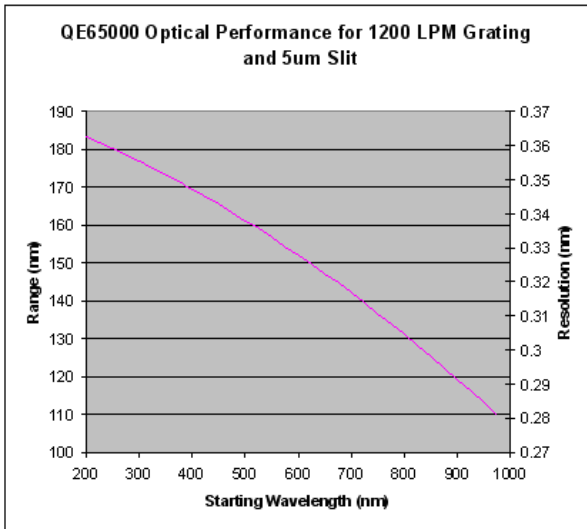
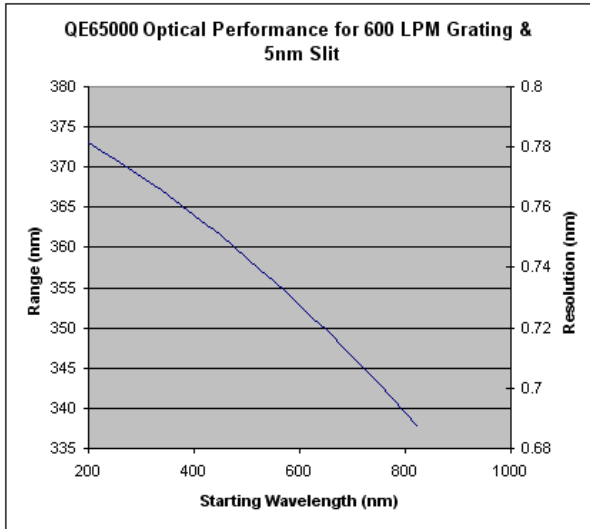
The graph below shows the total charge collected by the CCD in terms of electrons. While at first this may seem like a strange way to compare the overall sensitivity, it provides a good comparison between the two detectors. Basically the QE65 Pro has the good S/N of a deep well device but the sensitivity 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 μ m slit.

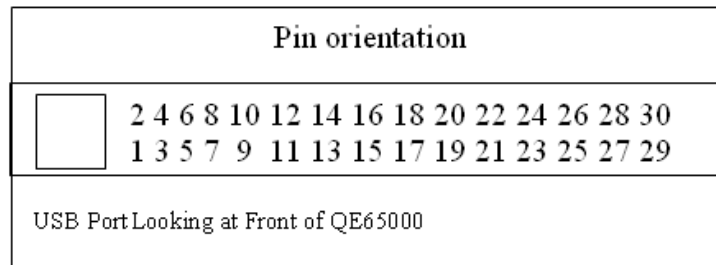


The following table shows the resolution for various slit sizes.

| | | 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 |

Electrical Pinout

Listed below is the pin description for the QE65 Pro 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-EA (requires two: 1.27mm (50 mil) flat ribbon cable: Recommended 3M 3365 Series)

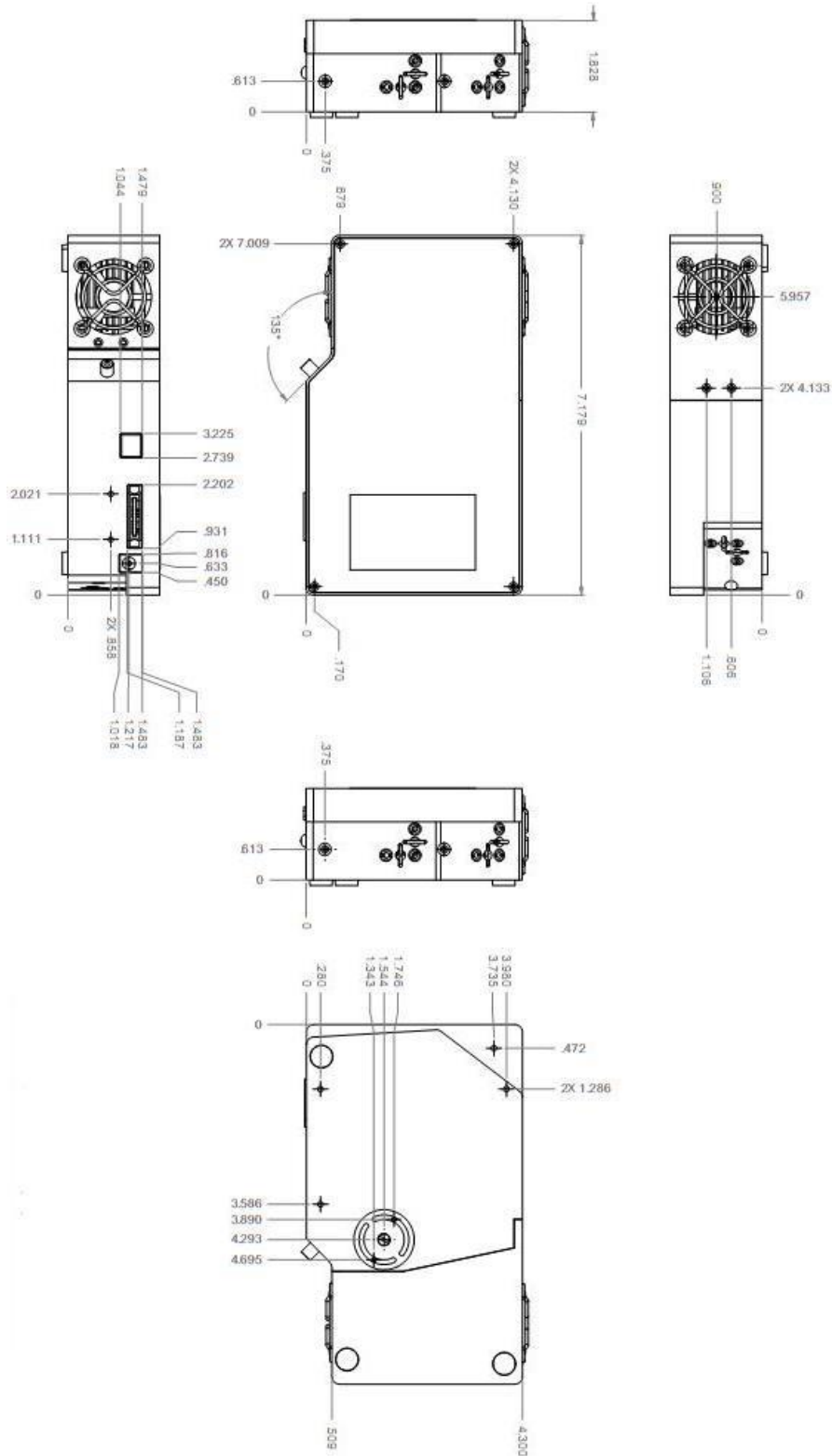


| Pin # | Function | Input/Output | Description |
|-------|-----------------|--------------|---|
| 1 | RS232 Rx | Input | RS232 receive signal – Communicates with a PC over DB9 Pin 3 |
| 2 | RS232 Tx | Output | RS232 transmit signal – Communicates with a PC over DB9 Pin 2 |
| 3 | GPIO (2)* | Input/Output | 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 |

QE65 Pro Data Sheet

| Pin # | Function | Input/Output | Description |
|--|-------------------|-----------------|---|
| 11 | GPIO (3)* | Input/Output | Integration clock |
| 12 | VCC or 5VIN | Input or Output | Input power pin for QE65 Pro – 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 QE65 Pro – 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 |
| 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. | | | |

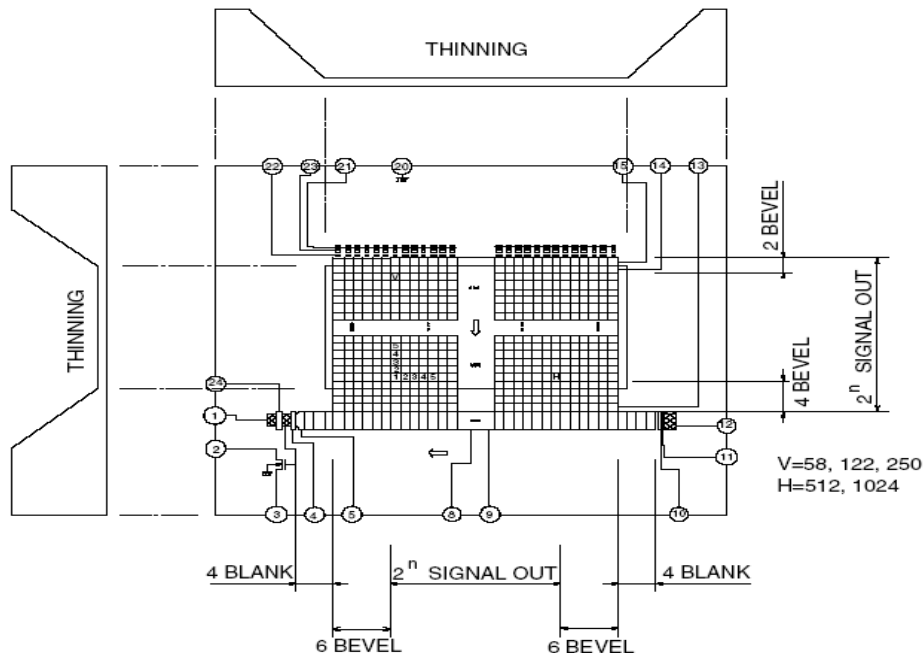
Mechanical Diagram



QE65 Pro Pixel Definition

The QE65 Pro contains a Hamamatsu S7031-1006 CCD which is a two dimensional CCD. The QE65 Pro 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) | | |



QE65 Pro 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 |

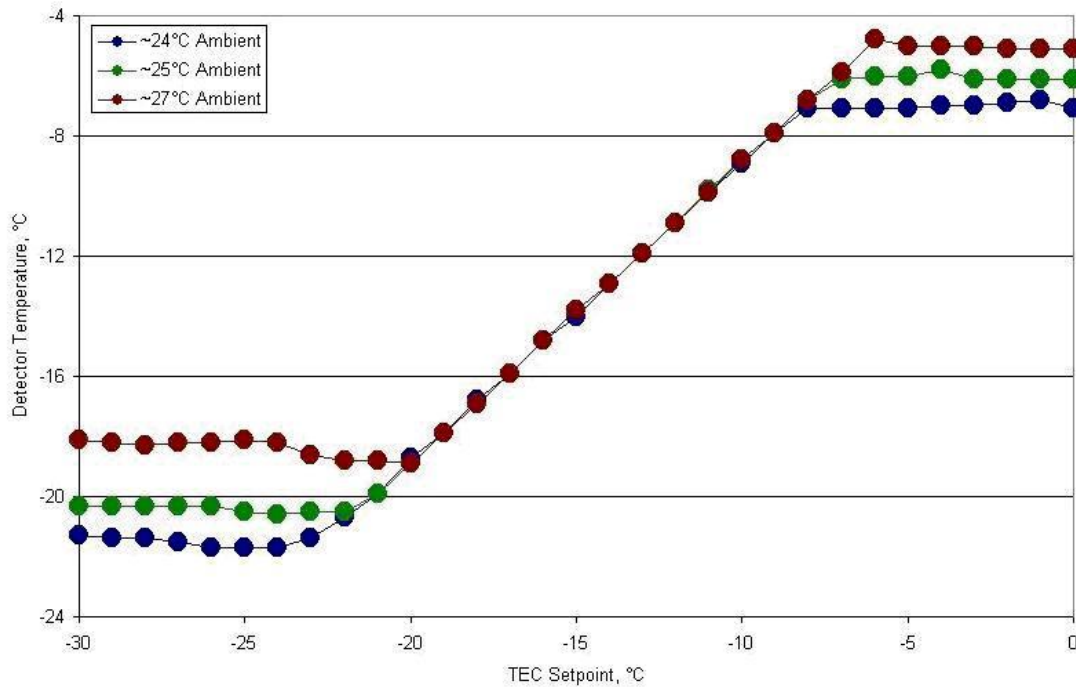
Pixels Provided by Software

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

QE65 Pro 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°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).

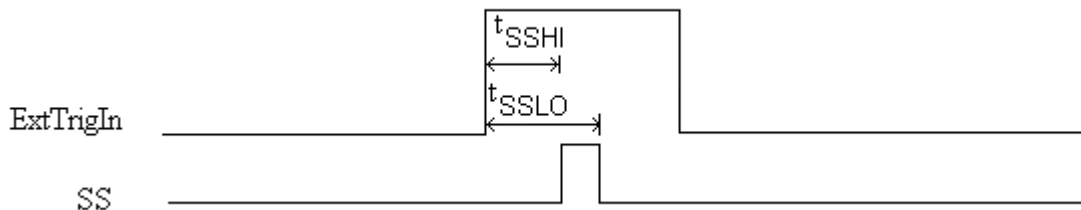
Wait approximately 2 seconds, and then read the TEC temperature. If the temperature hasn't responded as expected, repeat the sequence (up to 2 more times). If after a third try, the temperature still hasn't changed as expected, inform the user that TEC power is required to cool the detector. Note that 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 PIV vertical clock bursts). The timing diagram for the Single Strobe is shown below:



Single Strobe (External Hardware Trigger Mode)

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 2us to 60s. This signal is continuous once enabled, but is not synchronized to the Start of Integration or External Trigger Input. The Continuous Strobe is only active if the Lamp Enable command is active.

Synchronizing Strobe Events

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

QE65 Pro Trigger/Acquisition Modes

The QE65 Pro 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 QE65 Pro 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 QE65 Pro.
- **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.

QE65 Pro USB Port Interface Communications and Control Information

The QE65 Pro 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 QE65 Pro 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 QE65 Pro. Only experienced USB programmers should attempt to interface to the QE65 Pro via these methods.

Hardware Description

The QE65 Pro 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 E²PROM that are loaded at boot-up via the I²C 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 QE65 Pro 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 QE65 Pro | 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 ² C Read | 0.90.0 |
| 0x61 | General I ² 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 QE65 Pro 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 QE65 Pro

Description: Initializes certain parameters on the QE65 Pro 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 QE65 Pro 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 QE65 Pro 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 |
|--|

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 th order Wavelength Calibration Coefficient |
| 2 – 1 st order Wavelength Calibration Coefficient |
| 3 – 2 nd order Wavelength Calibration Coefficient |
| 4 – 3 rd order Wavelength Calibration Coefficient |
| 5 – Stray light constant |
| 6 – 0 th order non-linearity correction coefficient |
| 7 – 1 st order non-linearity correction coefficient |
| 8 – 2 nd order non-linearity correction coefficient |
| 9 – 3 rd order non-linearity correction coefficient |
| 10 – 4 th order non-linearity correction coefficient |
| 11 – 5 th order non-linearity correction coefficient |
| 12 – 6 th order non-linearity correction coefficient |
| 13 – 7 th 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 – QE65 Pro 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 QE65 Pro 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 QE65 Pro.

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 QE65 Pro 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 I²C Read

Description: Performs a general purpose read on the I²C 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 I²C bus runs at 400KHz. The maximum number of bytes that can be read is 61.

Command Byte Format

| | | |
|---------------|--------------------------|---------------|
| Byte 0 | Byte 1 | Byte 2 |
| 0x60 | I ² C Address | Bytes to Read |

Return Byte Format

| Byte 0 | Byte 1 | Byte 2 | Byte 3 | ... | Byte N+3 |
|--------------------------|--------------------------|---------------|-------------|-----|-------------|
| I ² C Results | I ² C Address | Bytes to Read | Data Byte 0 | ... | Data byte N |

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

General I²C Write

Description: 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 | I ² C Address | Bytes to Write | Data Byte 0 | ... | Data byte N |

Return Byte Format

| Byte 0 |
|--------------------------|
| I ² 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 QE65 Pro. 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°C a value of -50 or $0xFFCD$ 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 QE65 Pro 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 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 QE65 Pro (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 QE65 Pro 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 μs – LSW MSW. Within each word order is LSB MSB |
| 6 | Lamp Enable | 0 – Signal LOW 1 – Signal HIGH |
| 7 | Trigger Mode Value | |
| 8 | Spectral Acquisition Status | 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:

QE65 Pro Serial Port Interface Communications and Control Information

Overview

The QE65 Pro 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 QE65 Pro via the RS-232 interface.

Hardware Description

The QE65 Pro 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 I²C 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 QE65 Pro “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 QE65 Pro 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 ~ 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 QE65 Pro should be compressed to speed data transfer rates. For more information on QE65 Pro 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 QE65 Pro'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 QE65 Pro'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 QE65 Pro'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 th pixel with no averaging 2 = N/A 3 = pixel x through y every n pixels 4 = up to 10 randomly selected pixels between 0 and 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 QE65 Pro’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 QE65 Pro). 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 QE65 Pro “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 QE65 Pro 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 QE65 Pro 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 100ths 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: | <p>DATA WORD Index description</p> <p>0 – Serial Number</p> <p>1 – 0th order Wavelength Calibration Coefficient</p> <p>2 – 1st order Wavelength Calibration Coefficient</p> <p>3 – 2nd order Wavelength Calibration Coefficient</p> <p>4 – 3rd order Wavelength Calibration Coefficient</p> <p>5 – Stray light constant</p> <p>6 – 0th order non-linearity correction coefficient</p> <p>7 – 1st order non-linearity correction coefficient</p> <p>8 – 2nd order non-linearity correction coefficient</p> <p>9 – 3rd order non-linearity correction coefficient</p> <p>10 – 4th order non-linearity correction coefficient</p> <p>11 – 5th order non-linearity correction coefficient</p> <p>12 – 6th order non-linearity correction coefficient</p> <p>13 – 7th order non-linearity correction coefficient</p> <p>14 – Polynomial order of non-linearity calibration</p> <p>15 – Optical bench configuration: gg fff sss gg – Grating #, fff – filter wavelength, sss – slit size</p> <p>16 – QE65 Pro configuration: AWL V A – Array coating Mfg, W – Array wavelength (VIS, UV, OFLV), L – L2 lens installed, V – CPLD Version</p> <p>17 – Reserved</p> <p>18 – Startup Baud Rate value</p> <p>19 – Reserved</p> |
| 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 4th 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 QE65 Pro may become out-of-synch with the controlling program. It is good practice to cycle power on the QE65 Pro when errors occur.
- If you question the state of the QE65 Pro, you can transmit a space (or another non-command) using a terminal emulator. If you receive a NAK, the QE65 Pro 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: QE65 Pro 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 QE65 Pro 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 QE65 Pro 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 QE65 Pro. 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: QE65 Pro 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 QE65 Pro include the following:

- Due to the architecture of the detector used on the QE65 Pro, it may be necessary to set the **Single Strobe Timing** setting using software 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 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.