Flame Miniature Spectrometer

Technical Specifications

For Products: FLAME-S, FLAME-T
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A HALMA COMPANY

AMERICAS & WORLD HEADQUARTERS

Phone: +1 727-733-2447
Fax: +1 727-733-3962

Sales: info@oceanoptics.com
Orders: orders@oceanoptics.com
Support: techsupport@oceanoptics.com

Ocean Optics, Inc.
830 Douglas Ave.
Dunedin, FL 34698
USA

Manufacturing & Logistics
4301 Metric Dr.
Winter Park, FL 32792
USA

EUROPE, MIDDLE EAST & AFRICA

Phone: +31 26-319-0500
Fax: +31 26-319-0505
Email: info@oceanoptics.eu

Germany : +49 711-341696-0
UK : +44 1865-811118
France : +33 442-386-588

Sales & Support
Geograaf 24
6921 EW Duiven
The Netherlands

Manufacturing & Logistics
Maybachstrasse 11
73760 Ostfildern
Germany

ASIA

Phone: +86 21-6295-6600
Fax: +86 21-6295-6708
Email: asiasales@oceanoptics.com

Japan & Korea: +82 10-8514-3797

Ocean Optics Asia
666 Gubei Road
Kirin Tower Suite 601B
Changning District
Shanghai
PRC, 200336

www.oceanoptics.com

Flame Technical Specifications

This document contains the technical specifications for the FLAME-S and FLAME-T. For more information on the Flame spectrometers, including installation, configurations, operation with OceanView, troubleshooting tips, and firmware protocol commands, please see the *Flame User Manual*. For more information on Ocean Optics products, please visit our website at www.oceanoptics.com.

Specifications Table

Specification	FLAME-S	FLAME-T
Optical and Spectroscopic		
Integration Time	1 ms – 65 seconds	3.8 ms to 10 seconds
Dynamic Range for single acquisition[1]	1300:1	
Dynamic Range of system[2]	2×10^8	3.4×10^6
Signal-to-Noise (single acquisition)	250:1	300:1
Resolution (FWHM)	0.1 – 10.0 nm (configuration dependent)	
Stray Light	<0.05% at 600 nm <0.10% at 435 nm	
Scan rate (max)[3]	400 Hz	260 Hz
Spectrometer Channels	One	
Thermal Stability	0.02 nm/°C for 650 nm range, 0.06 pixels/°C	
Triggering	4 modes	
Triggering Jitter	21 nanoseconds	
Detector		
Type	Sony ILX511B CCD	Toshiba TCD1304AP CCD
Detector range	190-1100 nm	
Pixels	2048 pixels	3648 pixels

Specification	FLAME-S	FLAME-T
Pixel size	14 µm x 200 µm	8 µm x 200 µm
Electronic shutter	No	Yes
Pixel well depth	~62,500 electrons	~100,000 electrons
Readout noise (single dark spectrum)	50 counts RMS, 300 counts peak-to-peak	
Corrected linearity	>99.8%	
Filters (optional)	2nd and 3rd order rejection, long pass	
Electrical		
Power requirement (spectrometer functions)	250 mA at +5 VDC	
Supply voltage	4.75 – 5.25 V	
Power-up time	~2s	
Connectors	Micro-USB and JAE DD4 (DD4RA40JA1) 40-pin connector	
Micro-USB Absolute Maximum Ratings: V_{CC}	+ 5.5 VDC	
DD4 Absolute Maximum Ratings: V_{CC} (Pin 40) Voltage on any pin (other than input power)	+ 5.5 VDC +4VDC	
Interface: USB RS-232	USB 2.0, 480 Mbps 2-wire RS-232	
Mechanical		
Spectrometer Design	Asymmetric crossed Czerny-Turner	
Input Fiber Connector	SMA 905 or FC	
Gratings	15 different gratings	
Entrance Slit	5, 10, 25, 50, 100, or 200 µm slits. (Slits are optional. In the absence of a slit, the fiber acts as the entrance slit.)	
Physical Dimensions	88.9 mm x 63.5 mm x 31.9 mm	
Weight	265 g	

Specification	FLAME-S	FLAME-T
Environmental		
Temperature: Storage Operation	-30° to +70° C 0 to 50° C	
Humidity	0% - 90% noncondensing	
Compliance[4]		
Electrical	CE, FCC, CISPR 11:2010, EMC 2004/108/EC and EN 61326-1:2013	
Material	RoHS	
Shock	IEC 60068-2-64	
Vibration	IEC 60068-2-31	
Manufacturing	ISO:9001	

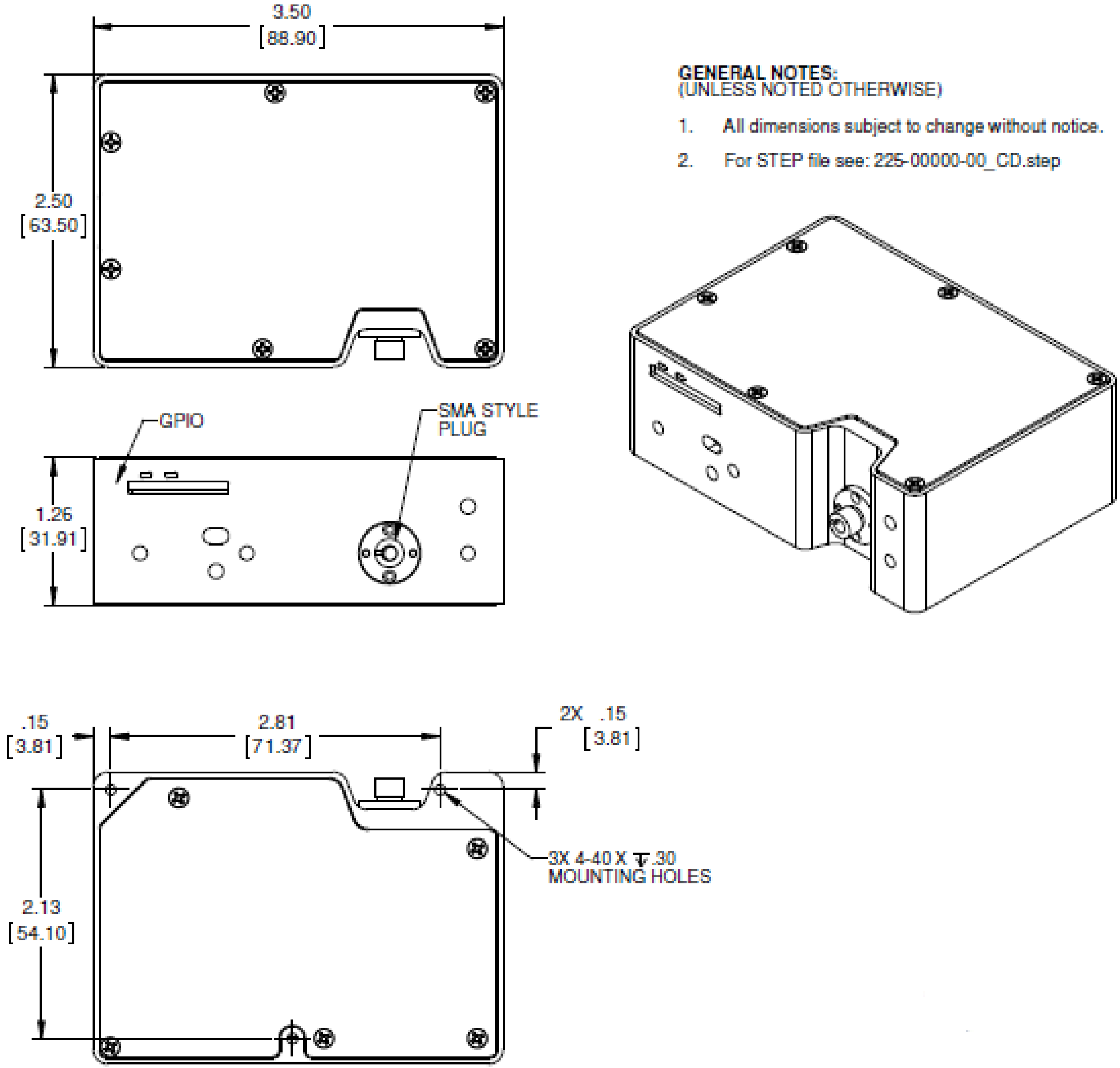
[1] Dynamic range for a single acquisition is a measure of the ratio of full signal to noise.

[2] Dynamic range of the system is the range of the detectable light level and can be thought of as the maximum detectable light level at the minimum integration time divided by the minimum detectable light level at the maximum integration time.

[3] Scan rate is dependent on the operating computer and not the spectrometer. These figures assume a non real-time operating system.

[4] Contact **info@oceanoptics.com** to obtain copies of certifications

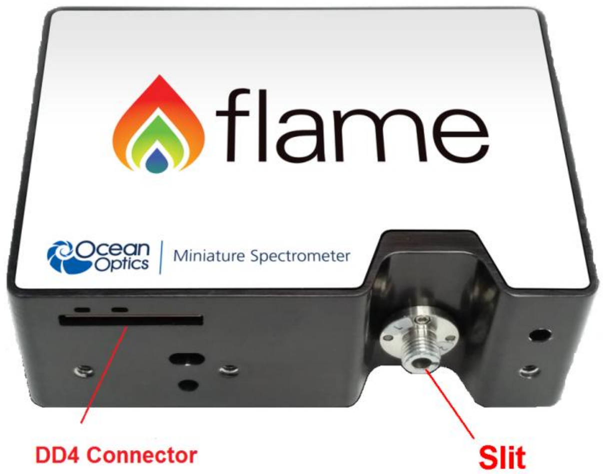
Mechanical Diagram



Flame Outer Dimensions

Electrical Pinout

The Flame features a 40-pin Accessory Connector, located on the front of the unit as shown:



Location of Flame Accessory Connector

DD4 Accessory Connector Pinout Diagram

When facing the 40-pin Accessory Connector on the front of the vertical wall of the Flame, pin number 1 is on the right.

Listed below is the pin description for the Flame Accessory Connector located on the front vertical wall of the unit. The Flame will include a JAE DD4 receptacle, part number DD4RA40JA1. Most accessories that plug into the Flame will include a JAE DD4 plug, part number DD4PA40MA1. There is also a vertical connector, JAE part number DD4BA40WA1.

Pin #	Function	Voltage Level	Description
1	Ground	N/A	Ground
2	Trigger	5 or 3.3 V	The TTL trigger signal.
3	Continuous Strobe	5 V	TTL output signal used to pulse a strobe that is divided down from the Master Clock signal.
4	Single Strobe	5 V	TTL output pulse used as a strobe signal, which has a programmable delay relative to the beginning of the spectrometer integration period.
5	Lamp Enable	5 V	A TTL signal that is driven Active HIGH when the Lamp Enable command is sent to the Flame.
6	GPIO 0	2.5 V	General Purpose Software Programmable Digital Inputs/Output*

Pin #	Function	Voltage Level	Description
7	GPIO 1	2.5 V	General Purpose Software Programmable Digital Inputs/Output*
8	GPIO 2	2.5 V	General Purpose Software Programmable Digital Inputs/Output*
9	GPIO 3	2.5 V	General Purpose Software Programmable Digital Inputs/Output*
10	Ground	2.5 V	General Purpose Software Programmable Digital Inputs/Output*
11	GPIO 4	2.5 V	General Purpose Software Programmable Digital Inputs/Output*
12	GPIO 5	2.5 V	General Purpose Software Programmable Digital Inputs/Output*
13	GPIO 6	2.5 V	General Purpose Software Programmable Digital Inputs/Output*
14	GPIO 7	2.5 V	General Purpose Software Programmable Digital Inputs/Output*
15	Ground	N/A	Ground
16	SPI Master Clock	3.3 V	Master clock. See **SPI** below.
17	SPI Master MOSI	3.3 V	The SPI Master Out Slave In (MOSI) signal for communications to other SPI peripherals. See **SPI** below.
18	SPI Master CS	3.3 V	TTL output signal used to pulse a strobe that is divided down from the Master Clock signal. See **SPI** below.
19	SPI Master MISO	3.3 V	The SPI Master In Slave Out (MISO) signal for communications to other SPI peripherals. See SPI below.
20	Ground	N/A	Ground
21	I^2C Master Clock	3.3 V	I^2C Master Clock. See I2C below.
22	I^2C Master Data	3.3 V	I^2C Master Data. See I2C below.

Pin #	Function	Voltage Level	Description
23	Ground	N/A	Ground
24	RS232 TX	-6 to +6 V	RS232 Transmit signal – for communication with PC connect
25	RS232 RX	N/A	RS232 Receive signal – for communication with PC connect
26	Reserved	N/A	Reserved
27	Reserved	N/A	Reserved
28	Reserved	N/A	Do not connect
29	Reserved	N/A	Reserved
30	Reserved	N/A	Reserved
31	Reserved	N/A	Reserved
32	Reserved	N/A	Reserved
33	Reserved	N/A	Reserved
34	Reserved	N/A	Reserved
35	Reserved	N/A	Reserved
36	Reserved	N/A	Reserved
37	Reserved	N/A	Reserved
38	5V Out	5 V	The input power pin from the Flame.
39	Ground	N/A	Ground
40	5V In	N/A	The input power pin to the Flame. Additionally when operating via a Universal Serial Bus (USB) this is the USB power connection (+5V) which can be used to power other peripherals (Care must be taken to insure that the peripheral complies with USB Specifications). The entire assembly should not draw more than 500 mA. NOTE: Do not connect both USB power and Auxiliary power (as an input) at the same time.
***See the Caution below.**			

Caution

Do not connect the GPIO pins to 5V. The GPIOs are not 5V tolerant and will be damaged if connected to 5V. The maximum voltage is 4V.

SPI

The Flame has the ability to function as a SPI master through the SPI port, which comprises the SPI Master Clock, SPI Master MOSI, SPI Master CS, and SPI Master MISO pins. To send messages over the SPI port, use the *General SPI Input/Output* message. The Flame does not send or receive any SPI data without direction from its host PC.

Because SPI is a full-duplex transaction, the *General SPI Input/Output* message both reads and writes at the same time. For instance, a four byte write will return four bytes of dummy read data, and a four byte read requires four bytes of dummy write data:

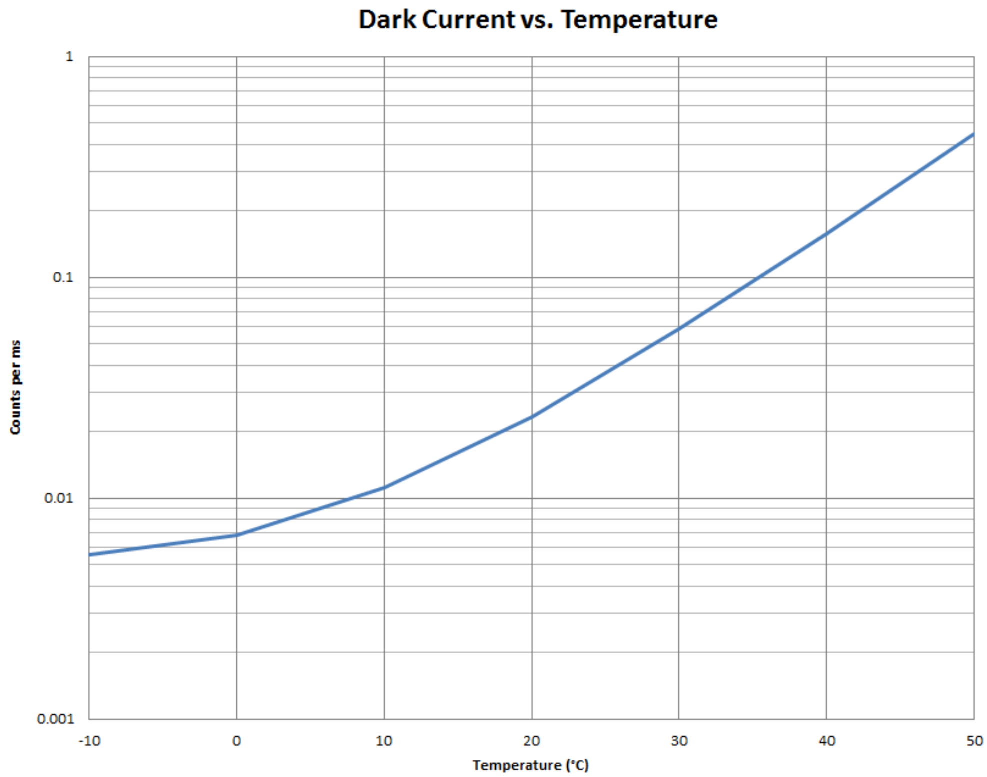
- MOSI data is established just prior to the rising edge of the SPI clock
- MISO data is sampled just after a falling edge of the SPI clock.

I2C

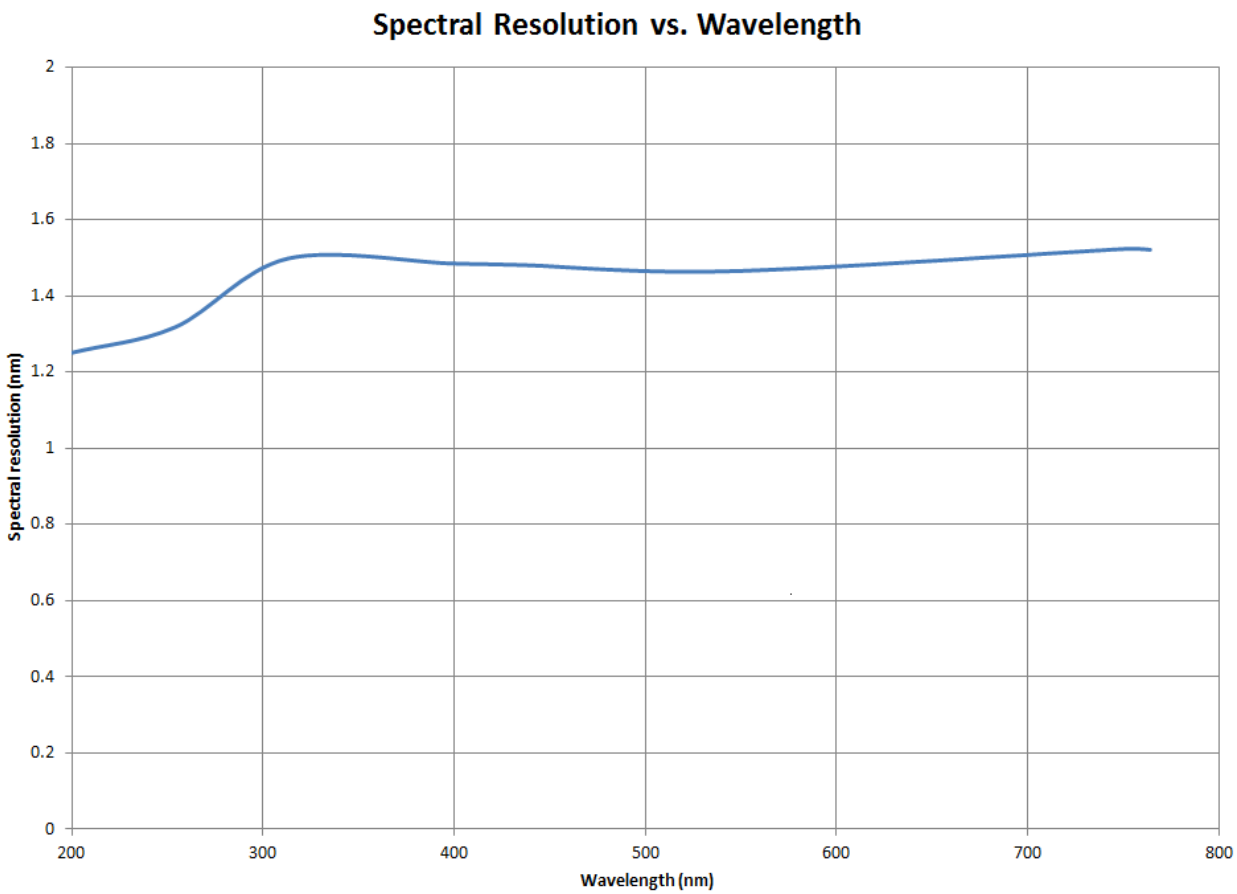
The Flame has the ability to function as an I2C master through the I2C port, which comprises the I2C-SDA, and I2C-SCL pins. To send messages over the I2C port, use the General I2C Write and General I2C Read messages. Note that the Flame does not send or receive any I2C data without direction from its host PC. The I2C lines are pulled up internally to 3.3V by 2K resistors.

Performance Charts

The following show some performance characteristics of the Flame-S.



This is a plot of the dark current (in counts per millisecond) versus temperature (°C). Since dark current is expressed as a rate, the average baseline will go up as integration time is increased. How rapidly the baseline increases with integration time is a function of temperature. This graph provides an indication of what to expect. Note that the y-axis is a log plot.



Measured on a FLAME-S-UV-VIS with a 25 µm slit

This is a plot of the spectral resolution of Flame-UV-VIS across the wavelength range of the device. The spectral resolution is calculated by the FWHM of several peaks in an HG-1 spectrum (mercury/argon line source). The resolution in nm is relatively flat across most of the spectral range.

CCD Overview

CCD Detector

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

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

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

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

CCD Well Depth

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

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

1. Use a large-well device that integrates to saturation over a long period of time until the photon noise is averaged out by the root of *n* multiples of a defined short Δt.
2. Use a small-well device that integrates to saturation at one short Δt and then signal average mathematically *n* times.

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

Well Depth Comparison

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

Signal Averaging

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

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

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

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

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

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

Internal Operation

Pixel Definition

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

Pixels on the FLAME-S

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

Pixels on the FLAME-T

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

Pixels Read from the Flame-S via USB

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

It is important to note that the Flame-S only digitizes the first 2048 pixels. For Flame-T, Ocean Optics software displays 3648 pixels starting at pixel 1 above. In RS232 interface mode, the USB4000 transmits out the first 3670 pixels.

CCD Detector Reset Operation

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

Timing Signals

Strobe Signals

Single Strobe

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

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

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

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

An example calculation of the Single Strobe timing follows:

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

Continuous Strobe

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

Synchronizing Strobe Events

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

External Triggering

The Flame Spectrometer has several ways of acquiring data. In the Normal/Free-Run mode, the spectrometer is "free running." That is, the spectrometer is continuously scanning, acquiring, and making data available to your computer, according to parameters set in the software. In this mode, there is no way to synchronize the scanning, acquisition, and transfer of data with an external event. However, trigger pulses for synchronizing an external event with the spectrometer are available.

Each trigger mode involves connecting an external triggering device to the spectrometer and then applying an external trigger to the spectrometer before the software receives the data. The length of the integration time and the source for the integration clock depend upon the mode chosen. All other acquisition parameters are set in the software.

You can trigger the Flame using a variety of External Triggering options through the 40-pin Accessory Connector on the spectrometer. See the External Triggering Options document located at http://oceanoptics.com/wp-content/uploads/External-Triggering-Options_Firmware3.0andAbove.pdf. The triggering document contains further instructions for configuring External Triggering options for the Flame.

Triggering Modes

The Flame supports three triggering modes, (plus Normal mode), which are set with the Trigger Mode command. Detailed information of each triggering mode follows. Also refer to the External Triggering Options document located on our website at http://oceanoptics.com/wp-content/uploads/External-Triggering-Options_Firmware3.0andAbove.pdf. The following paragraphs describe these modes.

Normal

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

External Synchronous Trigger Mode

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

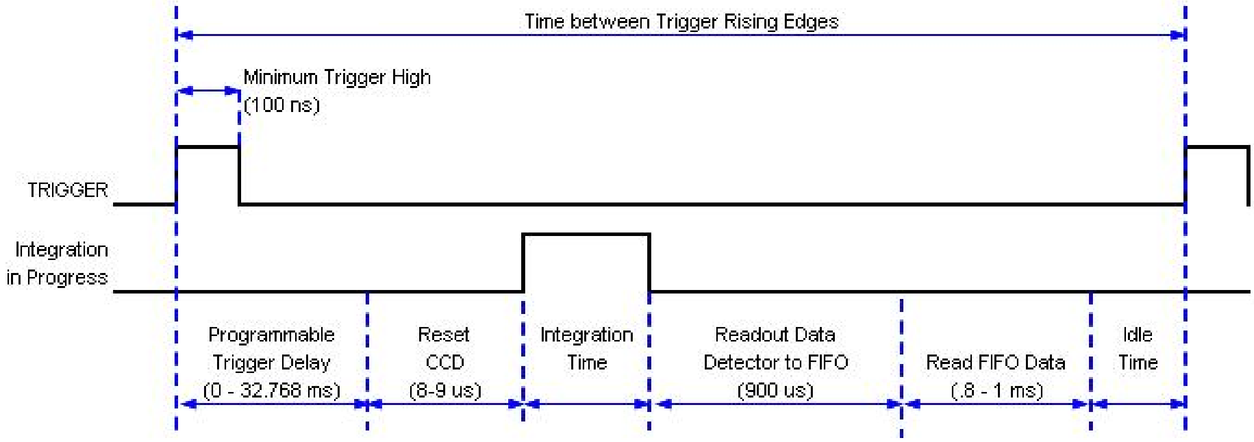
External Hardware Level Trigger Mode

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

External Hardware Edge Trigger Mode

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

Flame -- Timetable for Hardware Edge Trigger Mode



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

See *DD4 Accessory Connector Pinout* Diagram to locate the pins to set up triggering.