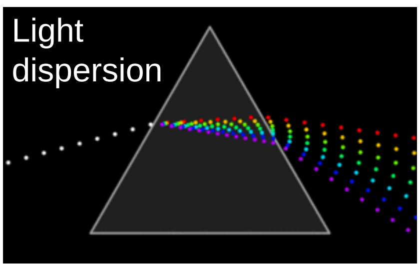
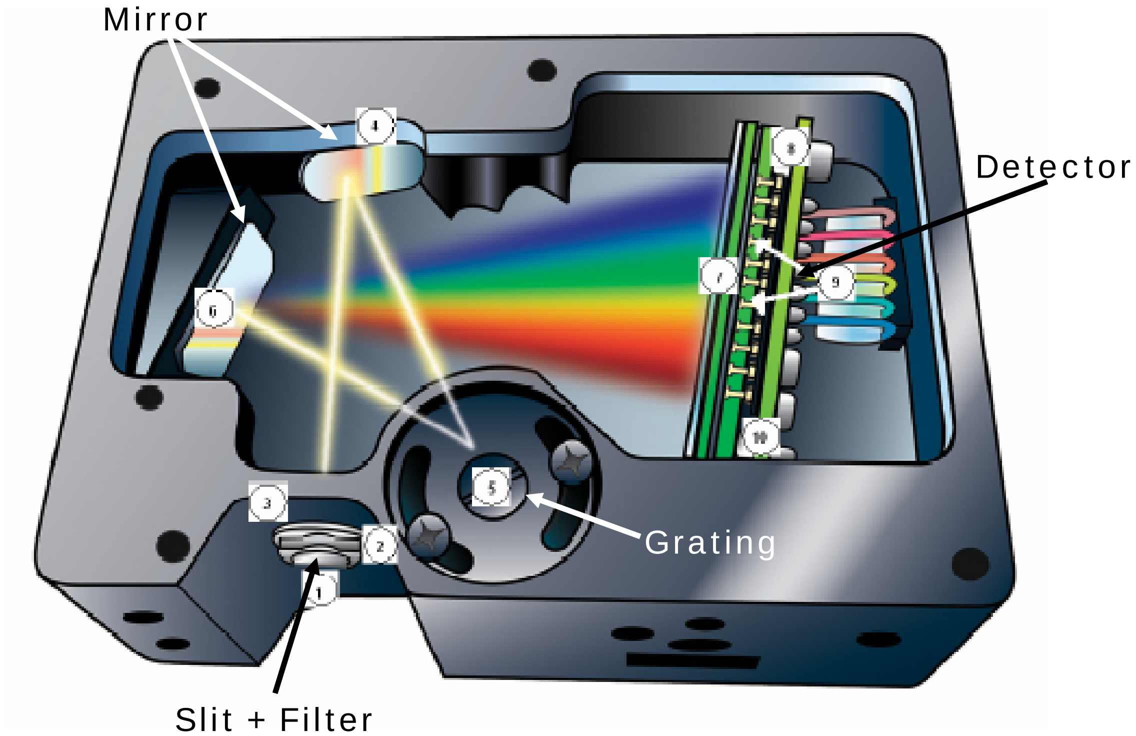
Spectrometer

ESS3271 Lecture

Spectrometer

- An optical instrument used to measure properties of light over a specific portion of the electromagnetic spectrum
- The variable measured is most often the light's intensity
- A spectrometer is used in spectroscopy for producing spectral lines and measuring their wavelengths and intensities

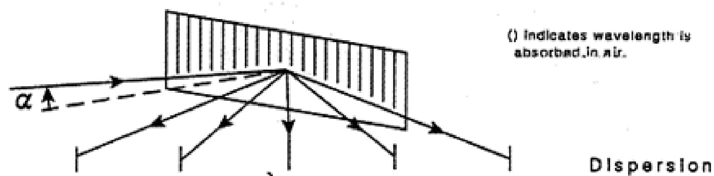




USB4000 Spectrometer with Components

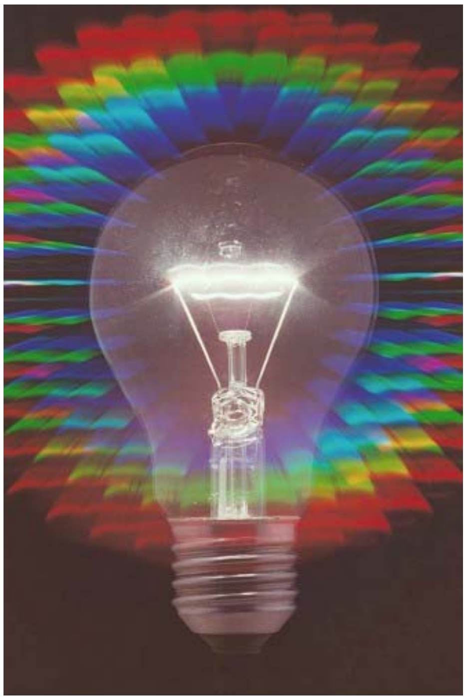
Diffraction Grating

- An optical component with a surface covered by a regular pattern of parallel lines, typically with a distance between the lines comparable to the wavelength of light
- Light rays that pass through such a surface are bent as a result of diffraction, related to the wave properties of light
- This diffraction angle depends on the wave-length of the light

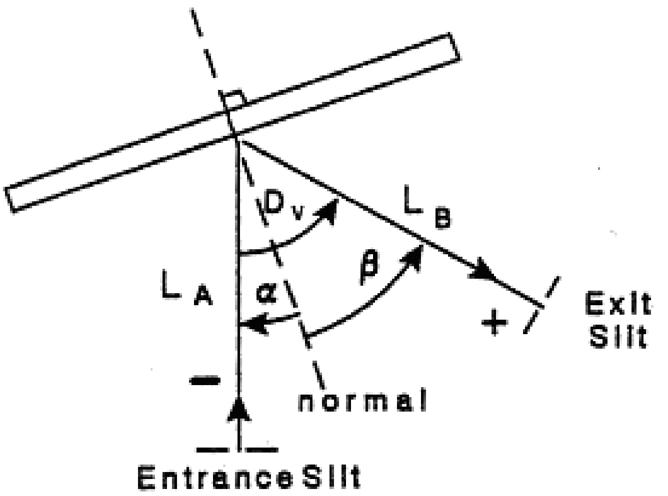


() indicates wavelength is absorbed in air.

Order						Dispersion at Central Wavelength
1st	200	400	600	800	1000	10 nm/mm
2nd	(100)	200	300	400	500	5
3rd	(66.6)	(133.3)	200	266.6	333.3	3.3
4th	(50)	(100)	(150)	200	250	2.5



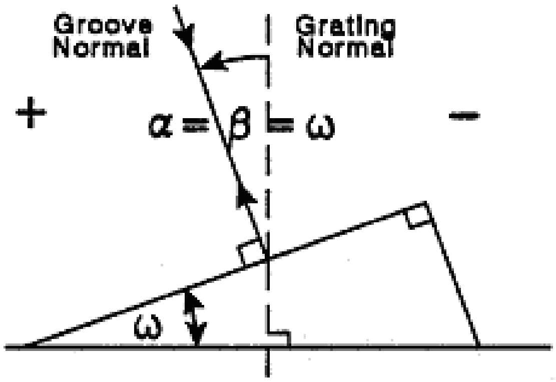
Grating Equation



$$\sin\alpha + \sin\ \beta = 10^{-6}\ kn\lambda$$

k: diffraction order and n: groove density (g/mm)

Littrow Condition



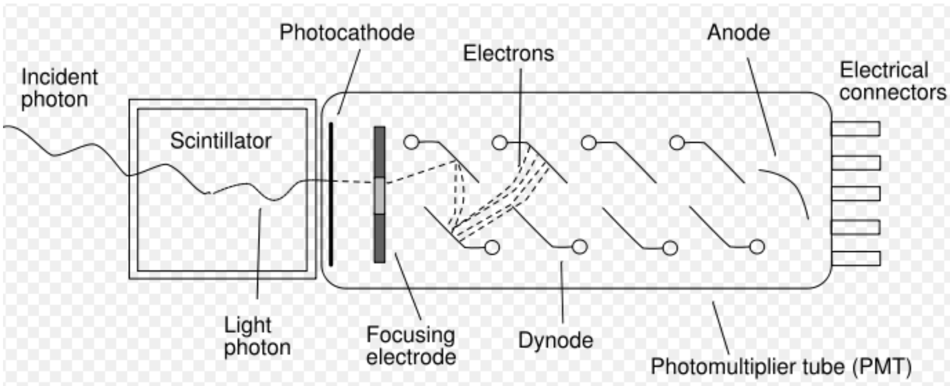
$$\sin\alpha + \sin\beta = kn\,\lambda_B 10^{-6}$$

$$\omega = \alpha = \beta \quad \text{where } \omega = \text{the blaze angle}$$

$$2\sin\omega = kn\,\lambda_B 10^{-6}$$

Photomultiplier Tube (PMT)

- Extremely sensitive detectors of light in the ultraviolet, visible and near infrared
- Multiply the signal produced by incident light by as much as 10^8, from which single photons can be resolved



PMT

- Photomultipliers are constructed from a glass vacuum tube which houses a photocathode, several dynodes, and an anode
- Incident photons strike the photocathode with electrons being produced as a consequence of the photoelectric effect
- These electrons are directed by the focusing electrode towards the electron multiplier, where electrons are multiplied by the process of secondary emission
- Each dynode is held at a more positive voltage than the previous one

STS Series OEM Microspectrometer

Amazing Full-Spectrum Performance in a Tiny Footprint

The STS introduces a family of compact, low-cost spectrometers that's ideal for embedding into OEM devices. At just 40 mm x 42 mm x 24 mm (1.6" x 1.7" x 0.9"), the STS provides full spectral analysis with low stray light (<0.2% SRPR @ 450 nm), high signal-to-noise ratio (>1500:1) and optical resolution (~1.5 nm FWHM) – remarkable performance for a spectrometer its size. The STS is an especially attractive option for high-intensity applications such as LED characterization and absorbance/transmission measurements, yet versatile enough for an extensive range of spectral sensing requirements.

Key Features

Full Spectral Analysis in a Small Footprint
CMOS-based unit is less than 50 mm (2") square, weighs just 68 g (2.4 oz.)

Ideal for OEM Devices
Compact unit available at low cost and reproducible in large production quantities

Remarkable Performance
Meets or exceeds optical resolution, stability, sensitivity and other performance criteria associated with larger, more expensive spectrometers

Built-in Shutter
A convenient feature for making dark measurements

Physical	
Dimensions:	40 mm x 42 mm x 24 mm
Weight:	68 g (2.4 oz.), incl. fixed fiber
Operating temperature:	0-50 °C, 10 °C change/hour ramp
Storage temperature:	-20 to +75 °C
Detector	
Detector type:	ELIS-1024, 1024 pixel linear CMOS
Detector range:	200-1100 nm (uncoated)
Pixels/size:	1024, 7.8 x 125 µm
Pixel well depth:	800,000 e-
Optical Bench	
Design:	Crossed Czerny Turner, focal length 28 mm
Entrance aperture:	Shaped aperture; 25 µm or 100 µm slits (standard)
Gratings:	600 g/mm
Fiber optic connector:	25 cm x 400 µm fixed fiber (not detachable)
Quantum efficiency:	60% (@ 675 nm)
Spectroscopic	
Wavelength range:	VIS (350-800 nm), NIR (650-1100 nm)
Optical resolution:	FWHM 1.0 nm (10 µm slit), 1.5 nm (25 µm slit), 6.0 nm (100 µm slit), 12.0 nm (200 µm slit)
Signal-to-noise ratio:	>1500:1 (maximum signal)
A/D resolution:	14 bits
Dark noise:	<3 counts RMS
Dynamic range:	6 x 10^9 (system, 10 s max integration), 5600 single acq.
Integration time:	10 µs-10 s
Stray light:	≤0.2% @ 450 nm
Corrected linearity:	0.5% max deviation from best fit line (10-90% saturation)
Max dark current:	75 counts/second
Electronics	
Power consumption:	0.75 W (average)
Power options:	USB or GPIO port
Data transfer speed:	USB full speed
Acquisition time:	75 scans/second (max)
Connector:	Micro-USB
Inputs/Outputs:	GPIO
Trigger modes:	3 modes; breakout box also available
Strobe functions:	Single/Continuous
Gated delay feature:	Yes
Computer Requirements	
Computer interface:	USB 2.0, RS-232
Operating systems:	Any supported by OmniDriver/SeaBreeze or RS-232
Compliance	
CE mark:	Yes
RoHS:	Yes
Software	
Operating software:	SpectraSuite support (extra)
Dev. software:	OmniDriver/SeaBreeze driver support (extra)

STS Series OEM Microspectrometer

Amazing Full-Spectrum Performance in a Tiny Footprint

Robust Optical Bench Design

At the heart of the STS is a CMOS detector in a crossed Czerny Turner optical bench. The bench is distinguished by custom-molded collimating and focusing mirrors and a 600 lines/mm groove density grating that projects spectra onto the detector.

The unit achieves significantly better optical resolution and produces less stray light than most filter-based and other spectrometers of its size. For example, STS has 14-bit A/D resolution and has low power consumption of just 0.75 W. In addition, the STS is available with a built-in shutter for making dark measurements much simpler than manually blocking the light or turning off/on your light source. Plus, STS has triggering functions for instances when precise timing is necessary. For example, synchronizing measurements with an external event, such as the pulsing of an excitation lamp for fluorescence, is no challenge for the STS.

STS takes advantage of recent advances in CMOS detectors that elevate optoelectronic performance and improve system reproducibility. It uses a 1024-element ELIS-1024 linear image sensor that's responsive from 200-1100 nm and has excellent sensitivity (6.74V/lux-second typical). This new generation of CMOS detectors offers excellent performance with great value.

STS Options

We offer STS models for 350-800 nm (STS-VIS) and 650-1100 nm (STS-NIR) applications (a UV model is in development). Each unit has a fixed optical bench configuration, although you can select from standard slit sizes of 25 and 100 µm. Custom slits are also available. To optimize signal collection efficiency and improve reproducibility, STS utilizes a fixed-fiber design. The fiber has a 400 µm core and is 25 cm in length. Custom configurations are available for high-volume applications.

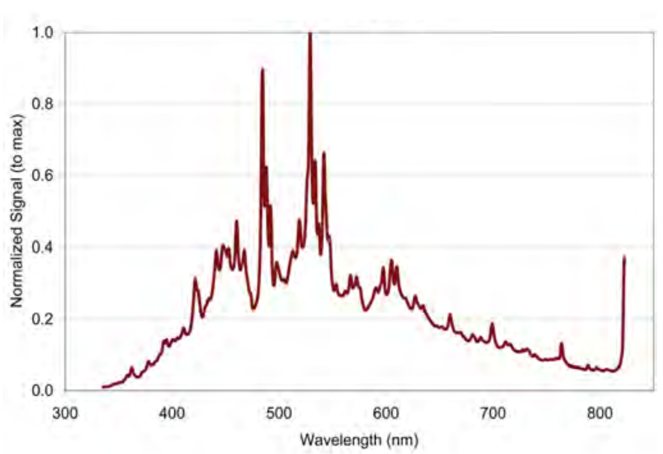
The STS is fully operational with SpectraSuite spectroscopy software – including the shutter control. Its shutter can be controlled through USB or RS-232 command. Operating software and software development tools are priced separately.

Markets and Applications

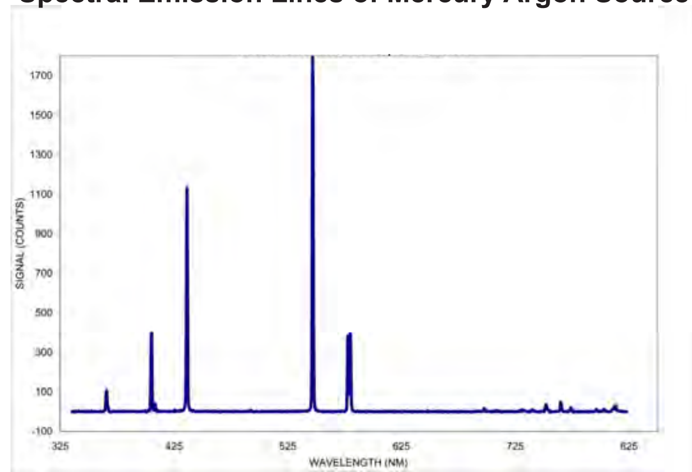
The STS was conceived as a low-cost, high-performance spectrometer for OEM and high-volume applications where one or more wavelengths are being monitored and a highly reproducible result is required. Life sciences, medical diagnostics, solid state lighting and environmental analysis are among the industries where STS is an attractive alternative to filter-based optical sensing systems and other microspectrometers.

*Minimum quantities required. Contact an Ocean Optics OEM Representative for details.

Sample Results with STS OEM Microspectrometer



Spectral Output of Xenon Flash Lamp



Spectral Emission Lines of Mercury Argon Source

Chapter 3

Controls and Indicators

Overview

SpectraSuite consists of a number of visual controls in the form of icons and buttons. This chapter describes these controls and how to use them.

Some menu selections and controls require that some action to be taken before they can be used. When unavailable, the controls are grayed-out. Many of these requirements will be lifted so that the software will ask what to do when it is not appropriate to take an action yet, but until then, the behavior is as follows:

Acquisition parameters, storing dark/reference spectra, and the Strip Chart require an unambiguous selection of an acquisition. If no acquisitions are running, try starting one. If more than one acquisition is started, try clicking on the desired trend in the graph to select the correct target. Similarly, try expanding the tree under the icon of the spectrometer and see how the controls respond to selecting each item. Right-click these items (or Control-click in MacOSX) to see additional actions for each.

Minus dark requires a dark spectrum to be stored.

A, T, R, and I (relative irradiance) require a dark and reference to be stored.

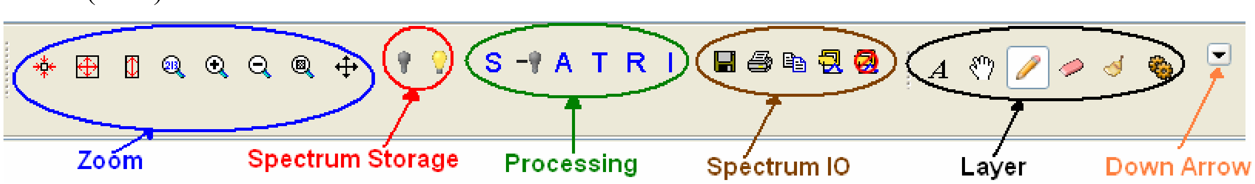
Absolute Irradiance mode (I) requires a calibration and a stored dark spectrum.

Photometry and energy/power/photons measurements require an active absolute irradiance calculation.

Graph Controls

The heart of the SpectraSuite application is the spectrum graph. SpectraSuite provides you with a wide variety of options to customize and monitor your graph views.

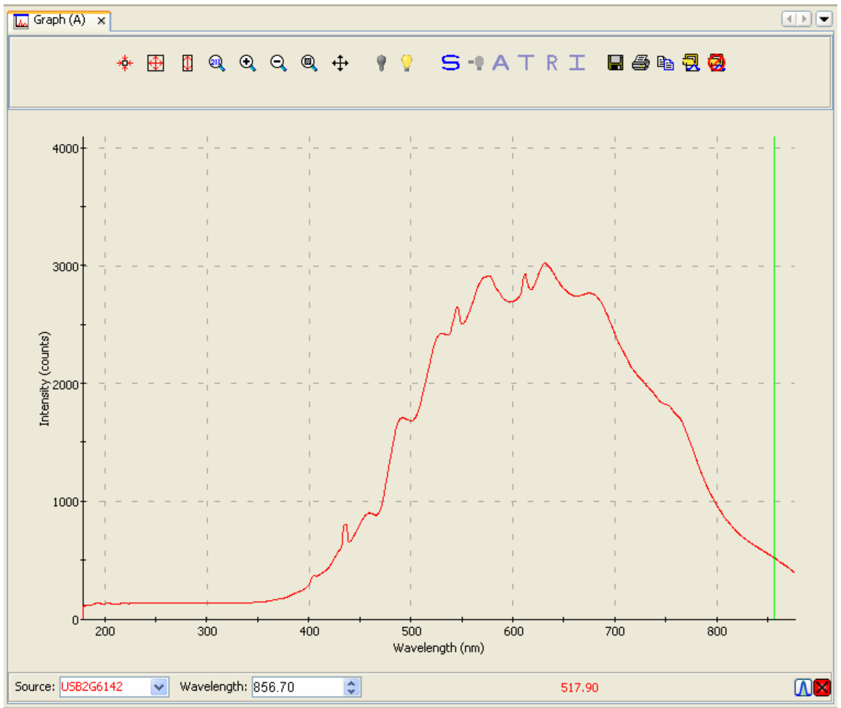
Controls are organized into the following toolbars that can be displayed or hidden using the Down Arrow button ().



Zoom Tools

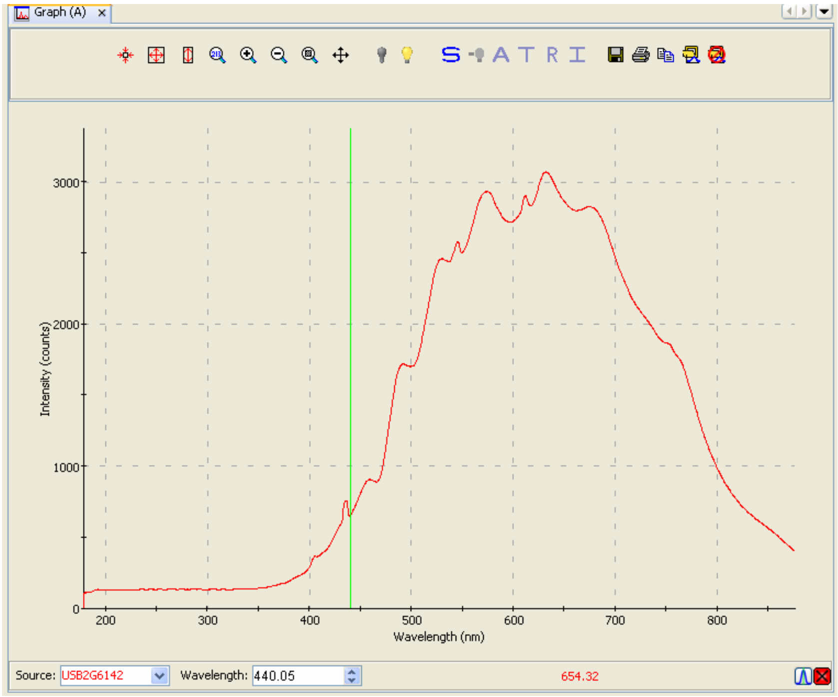
Zoom Out to Maximum

This control zooms out to display a full view of the spectrum graph.



Scale Graph to Fill Window

This control adjusts the graph display so that the section of the graph relevant to the spectrum line is shown, but no more. Both the x and y axis are adjusted. In this example, the graph is zoomed in so that the Y axis (Intensity) above 3500 no longer appears since the graph line does not extend that far.

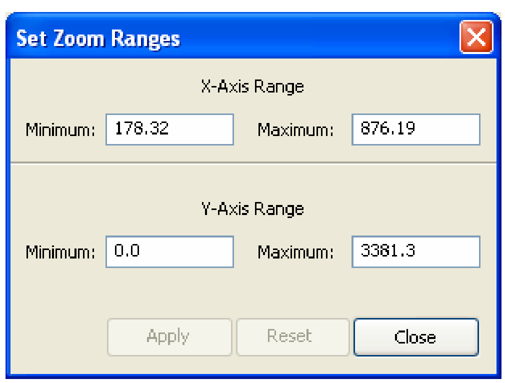


 Scale Graph Height to Fill Window

Use this control to zoom in on a graph so that the full height of the spectrum line is shown, but no more. Unlike the Scale Graph to Fill Window control, only the y axis is adjusted.

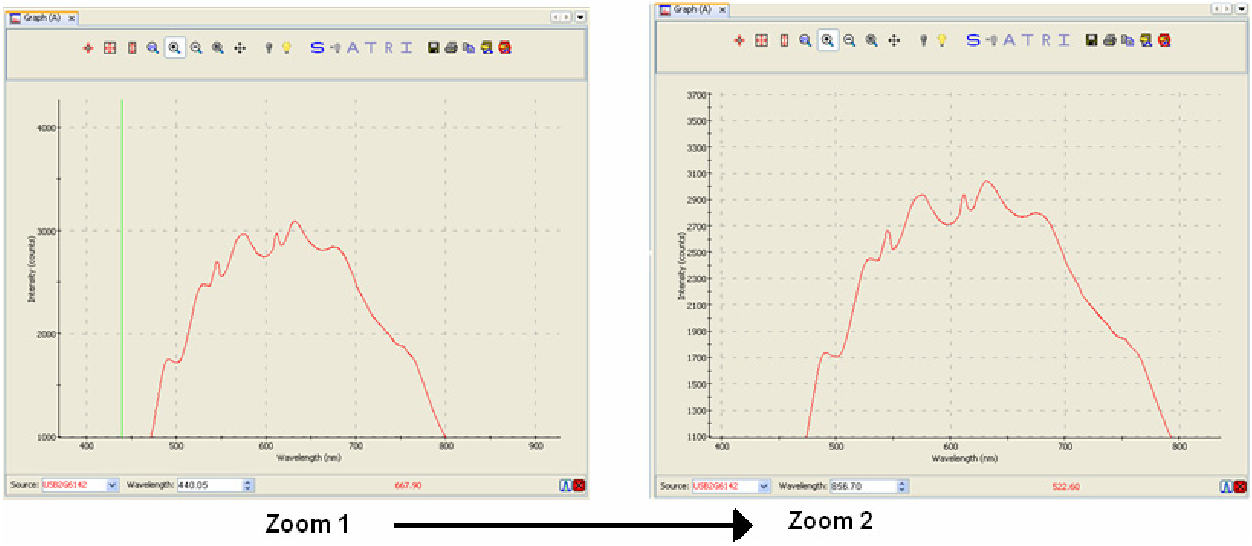
 Manually Set Numeric Ranges

This control enables you to set the exact zoom coordinates. When you click on the control, the Set Zoom Ranges dialog box appears so that you can enter the desired coordinates.



 Zoom In

Use this control to zoom in on the graph. Each time you click this control, the display zooms in further.



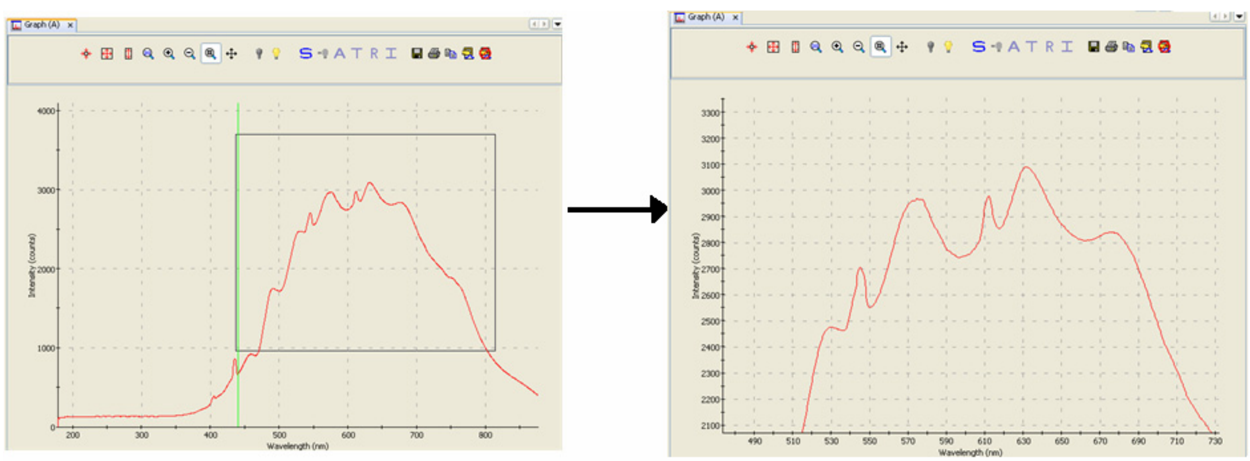
You can also use the mouse wheel to zoom in on the graph centered around the cursor (green vertical line).

Zoom Out

Use this control to reverse the zoom in process.

Zoom to Region

This control allows you to select a section of the graph to zoom in on. When you click the control, a cursor appears on the screen, enabling you to box-in a region to zoom in on.



Toggle Graph Pane

Use this control when you have more than one graph and want to switch between graph displays.

Spectrum Storage Tools

Icon	Meaning
	Store dark spectrum
	Store reference spectrum

These tools are also available from the **File | Store** menu. See *Store* for more information on these functions.

Processing Tools

Icon	Meaning
	Scope Mode
	Scope Minus Dark Mode
	Absorbance Mode
	Transmission Mode
	Reflection Mode
	Relative Irradiance Mode

These tools can also be accessed from the **Processing | Processing Mode** menu. See *Processing Mode* for more information on these functions.

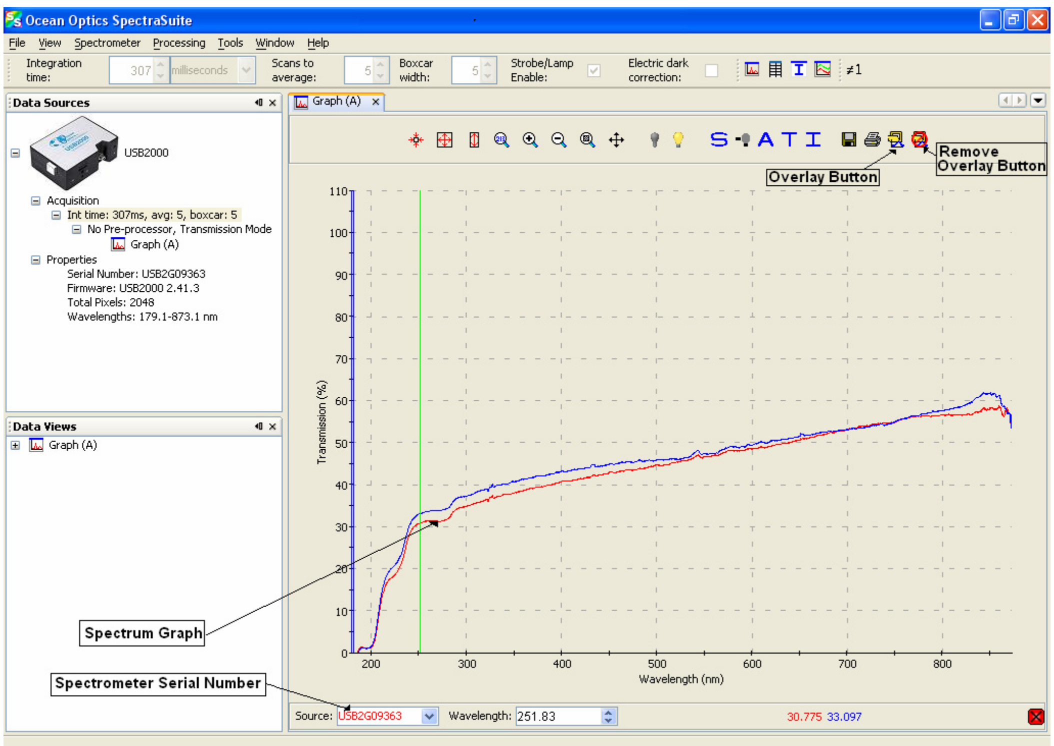
Spectrum IO Tools

Icon	Meaning
	Save Spectra. Click to save data in either a Grams SPC format, JCAMP format, binary format (which only SpectraSuite can read) or tab-delimited format (can be opened in an Excel spreadsheet).
	Opens the SpectraSuite Printing dialog box. Select what you want to print and to where (system printer, PDF file). You can select to print various layers on your graph, zoom in to a section of the graph, and add a title, if desired. You can adjust the font size and display of grid lines. The Preview button displays a view of how your printout will look.
	Copy spectral data to clipboard.

Icon	Meaning
	Overlay spectral data. Overlays a previously saved spectrum onto the current graph. See  *Overlay Spectral Data* for more information.
	Delete overlay spectra. Deletes any spectra that have been overlaid on the current graph.

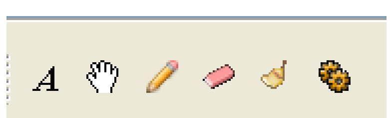
 Overlay Spectral Data

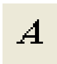
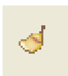
The Overlay Spectral Data control enables you to display a saved spectrum on the current spectrum. Click this control, and then browse for the file that you want to overlay on the current graph. The overlay shows the spectrometer serial number and the filename that you loaded the overlay from.



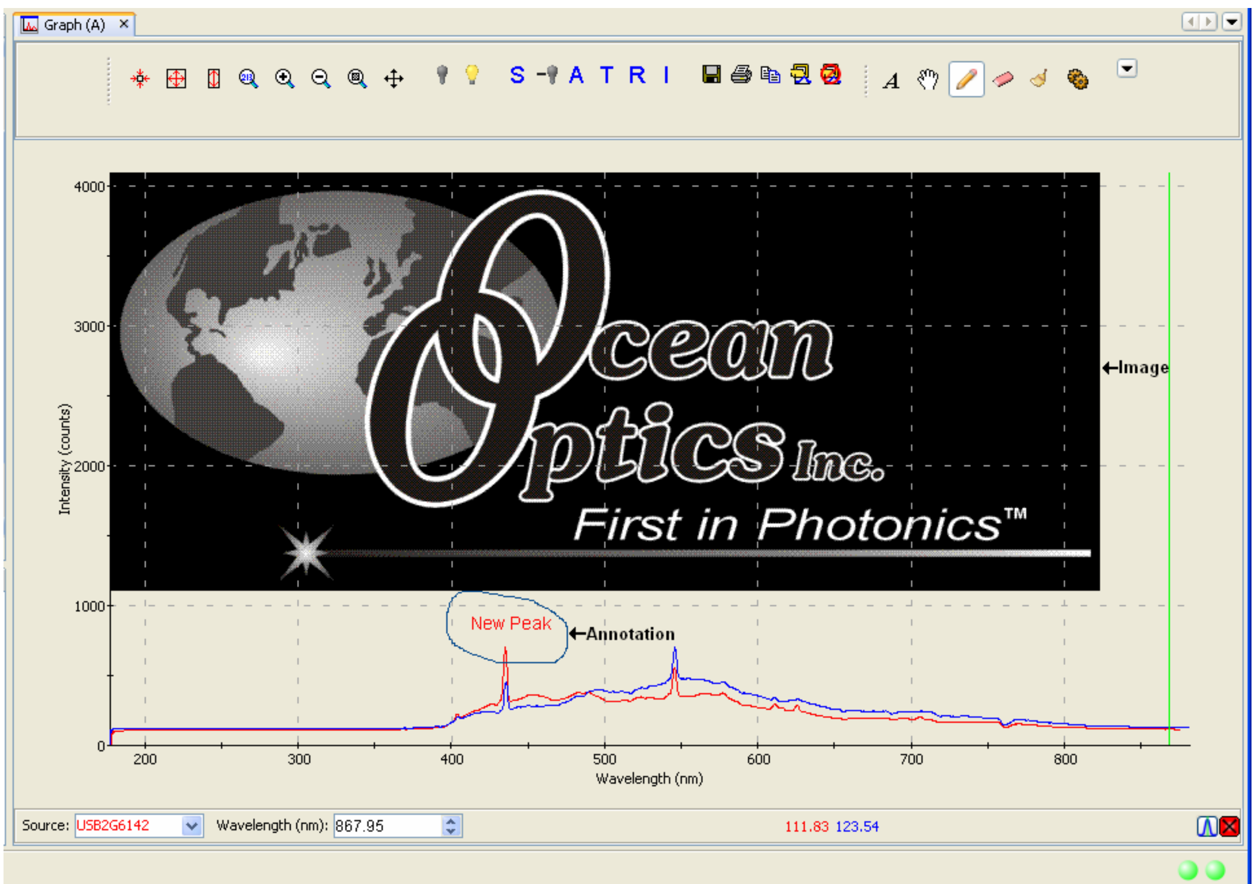
Layer Tools

The Layer tools provide you with functions to write captions and other meaningful data on your graphs. Select the tools using the Layer Toolbar.



Tool	Function
	**Add New Annotation**. Displays the New Annotation dialog box to add a new annotation to the selected graph.
	**Select and Drag Annotation**. Allows you to grab an annotation on the graph and drag it to another location.
	**Draw**. Allows you to draw freehand (using the mouse) on the graph.
	**Erase Areas of Drawing Layer**. Erases selected portions of the drawing created with the Draw tool (pencil).
	**Clear Drawing Layer**. Clears the entire drawing made with the Draw tool (pencil).
	**Graph Layer Options**. Displays the Graph Layer Options dialog box (see Graph Layer Options).

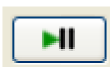
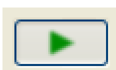
The following figure shows a graph with an image layer and an annotation circled with the drawing tool.



Other Controls

Acquisition Controls

Much like controls on a VCR, the Acquisition Controls allow you to pause and resume continuous spectra acquisition, and perform a single acquisition.

Control	Action
	Pause selected acquisition
	Perform single acquisition
	Resume selected acquisition

 Peak Finding

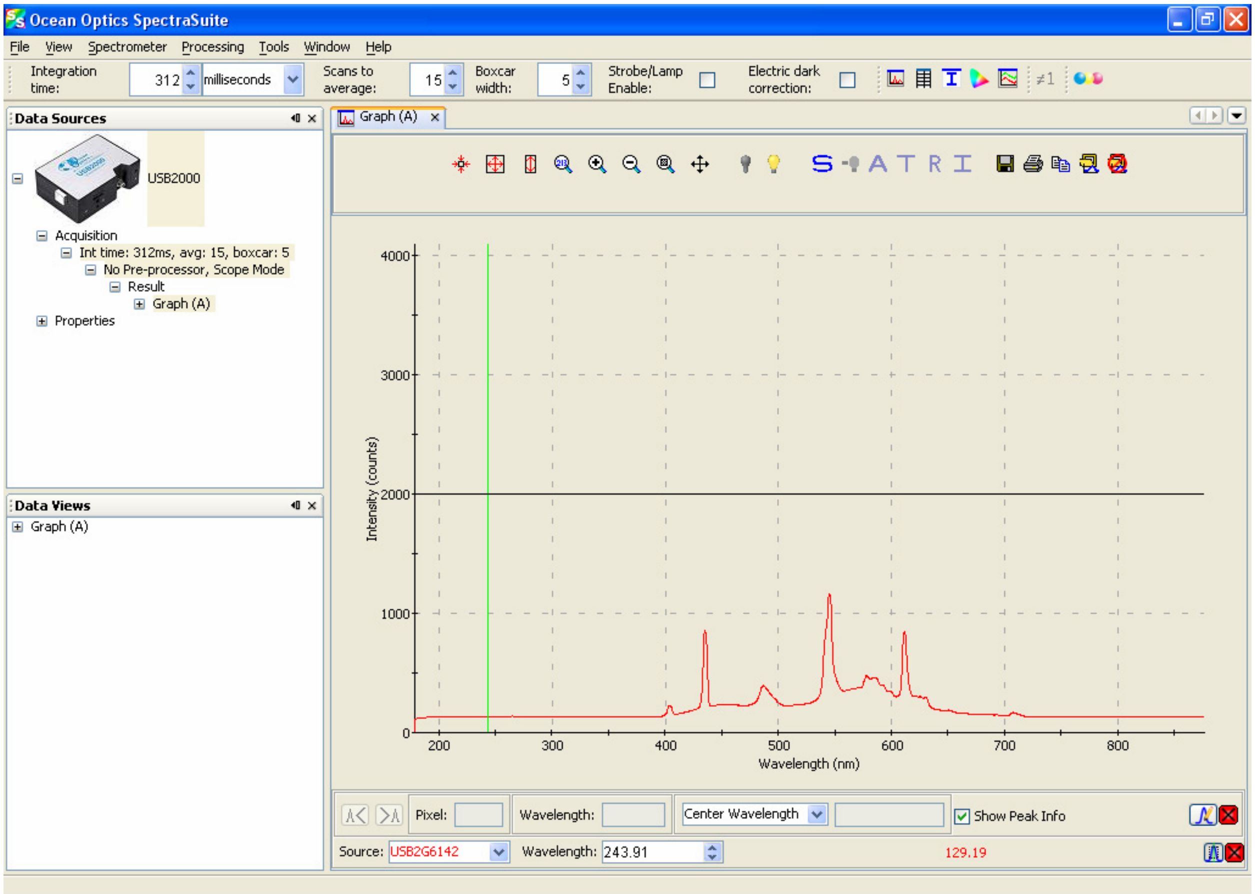
This control (located in the bottom, right corner of the graph) allows you to create a threshold on your spectral graph to isolate peaks.

Note

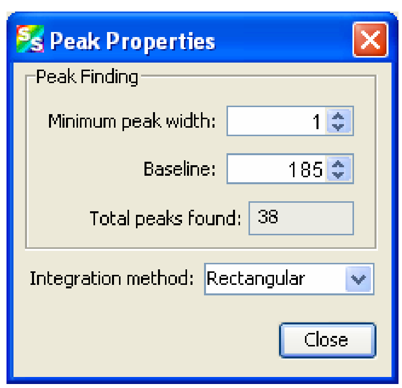
If this control does not display on your graph, click in the graph to make it appear.

► ***Procedure***

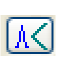
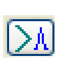
1. Click . A threshold line appears on the graph, along with more Peak Finding controls. The threshold is set high and in most cases, should be adjusted.



2. Click  to display the **Peak Properties** dialog box to set the threshold.



3. Set the threshold at the level needed to isolate the desired peaks. The threshold line moves into the location you selected.

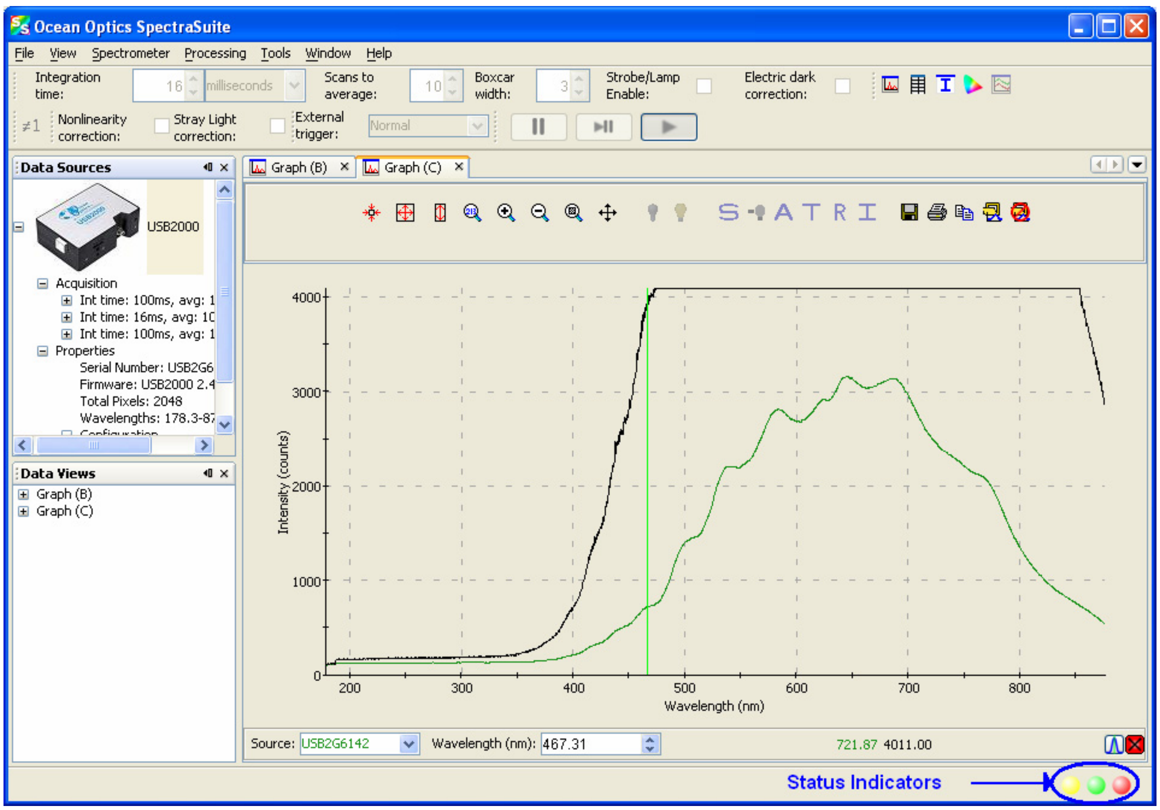
4. Use  and  to move the cursor to the next peak (left or right). The peak wavelength value appears in the **Wavelength** field below the graph.

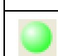
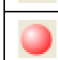
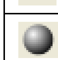
5. Check **Show Peak Info** checkbox to display peak data in the Pixel and Wavelength boxes.

Indicators

Status

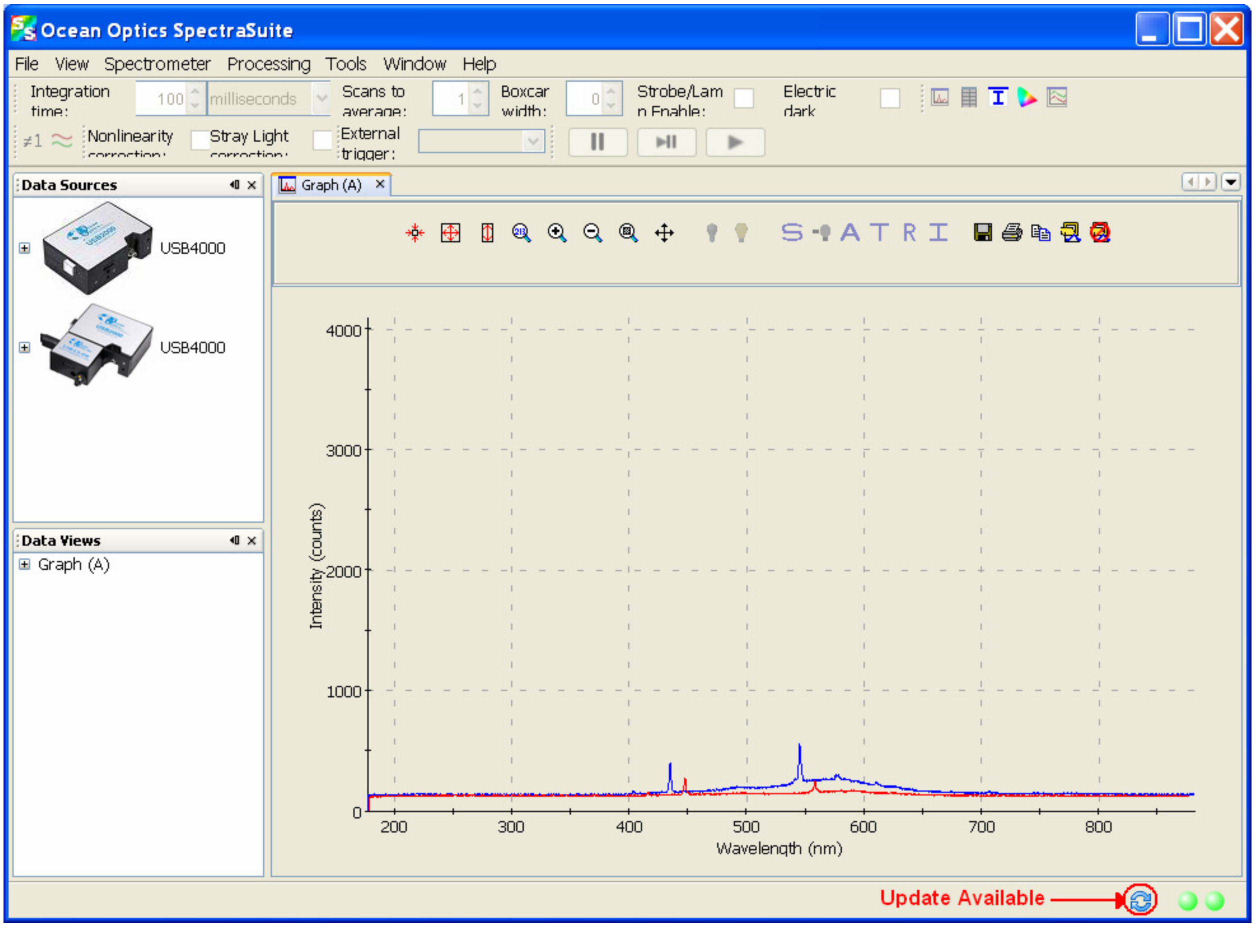
SpectraSuite provides you with feedback as to the status of the acquisitions you have graphed. The indicators refer to spectra shown on the graph currently displayed, as well as spectra on any other graphs that you have open (that appear on the graphs accessed from the tabs at the top of the screen). The feedback is in the bottom, right corner of the screen in the form of different colored circles. In the following example, two status indicators are shown for both spectral lines on Graph C, while a third indicator appears for the spectral line on Graph B.



Indicator	Meaning
	Recent acquisition within normal ranges
	Saturated signal
	Acquisition is paused
	Idle

Each circle corresponds to a graphed spectrum. If you pass the arrow pointer over a circle, it displays the spectrometer to which it refers and the related settings (e.g., **USB2G6142, Int time: 20 ms, avg: 10, boxcar: 3**). Click on a circle to select its associated spectrometer.

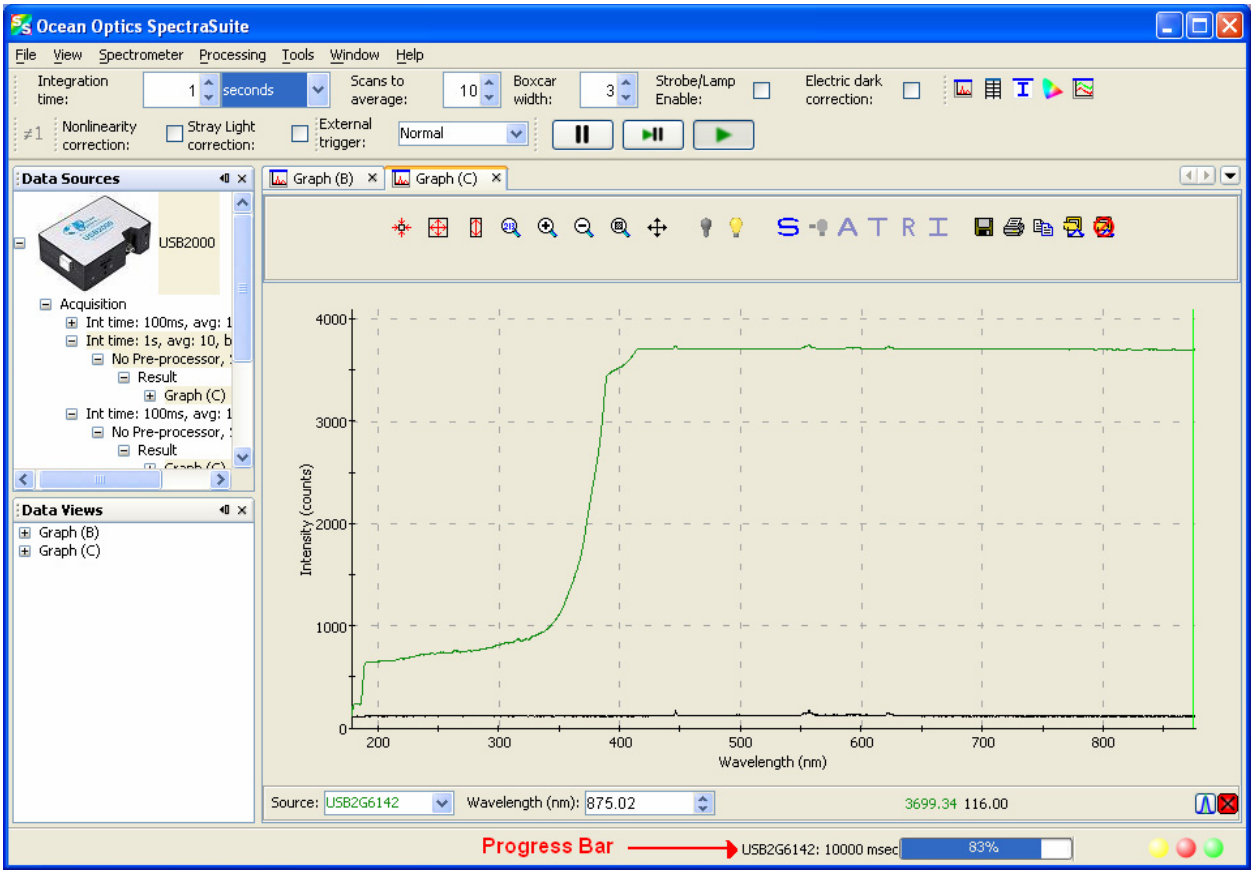
Update Available



Indicator	Meaning
	A software update is available to be downloaded. Go to **Tools | Update** center.

Progress Bar

If an acquisition takes longer than one second, a progress bar appears at the bottom of the screen. A progress bar can appear for each connected spectrometer that is acquiring data.

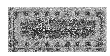


ONE TECHNOLOGY PLACE – HOMER, NEW YORK 13077
TEL: +1 607 749 2000 FAX: +1 607 749 3295 www.PanavisionImaging.com / sales@PanavisionImaging.com

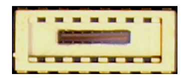
High Performance Linear Image Sensors
ELIS-1024 IMAGER

The Panavision Imaging ELIS is a high performance linear image sensor designed to replace CCD's in a wide variety of applications, including:

- **Edge Detection**
- **Contact Imaging**
- **Bar Code Reading**
- **Finger Printing**
- **Encoding and Positioning**
- **Text Scanning**



P/N: ELIS-1024A-LG
16-pin LCC package



P/N: ELIS-1024A-D-ES
16-pin ceramic DIP package

P/N: ELIS-1024A-CP-ES
CSP package (μBGA)

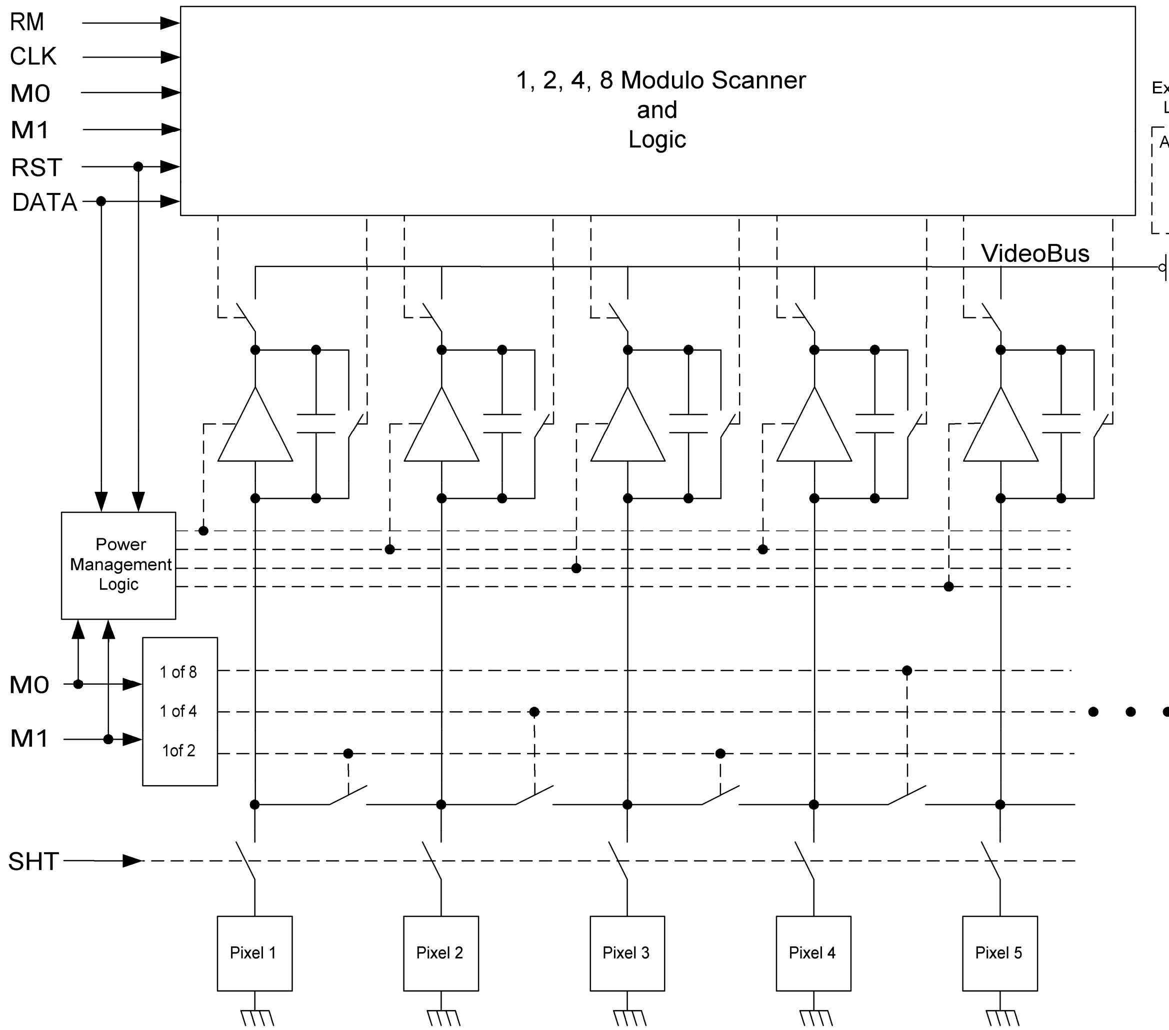
Description

The ELIS-1024 Linear Image Sensor consists of an array of high performance, low dark current photo-diode pixels. The sensor features sample and hold capability, selectable resolution and advanced power management. The device can operate at voltages as low as 2.8V making it ideal for portable applications. A key feature over traditional CCD technology is that the device can be read and reread Non-Destructively, allowing the user to maximize signal to noise and dynamic range. Internal logic automatically reduces power consumption when lower resolution settings are selected. A low power standby mode is also available to reduce system power consumption when the imager is not in use. Available in a low cost SMT package as well as a high performance dual inline ceramic package.

Key Features

- Low Cost
- Single Voltage Operation, Wide Operating Range
- Selectable Resolutions of 1024, 512, 256 and 128 pixels
- Intelligent Power Management and Low-Power Standby Mode
- Sample and Hold
- Full Frame Shutter and Dynamic Pixel Reset (DPR) Modes
- High Sensitivity
- High Signal to Noise
- Non-Destructive Read Capable, extremely low noise capable via signal averaging
- 1.0 kHz to 30.0 MHz Operation
- Very Low Dark Current
- Completely Integrated Timing and Control
- Replaces Entire CCD Systems, Not Just the Sensor

FUNCTIONAL BLOCK DIAGAM



PIN DESCRIPTION 16 Pin DIP and 16 LCC packages

PIN LCC & DIP	PIN CSP	Signal	I/O	Description
1, 12	A10, B1	AGND		Analog Ground
2, 11	A12, B3	AVDD		Analog Power
3	B5	DATA	Input	Start Readout
4	B7	RST	Input	Reset
5	B9	M0	Input	Bin Select Bit 0
6	B11	M1	Input	Bin Select Bit 1
7	B13	SHT	Input	Shutter
8, 9	--	N/C		No Connection
10	A14	VOUT	Output	Analog Video Output (requires external pull-up resistor)
13	A8	RM	Input	Reset Mode: RM = 0 for frame mode, RM = 1 for DPR mode
14	A6	DVDD		Digital Power
15	A4	DGND		Digital Ground
16	A2	CLK	Input	Master Clock (@ pixel rate)

Electro-Optical Characteristics

Specs given at 24°C, 5.0V, 1MHz clock with 50% duty cycle and a 3200K light source unless otherwise noted (Note 3).

Parameter	Min	Typical	Max	Units
Supply Current (see Note 1): Res = 1024 Res = 512 Res = 256 Res = 128		20.0 10.0 6.0 3.0		mA
Standby Current		16		μA
External Pull-up Load		5000		Ω
Output Voltage at Saturation (see Note 4) Vsat	4.5	4.8		V
Output Voltage at Dark Vdark	1.9	2.1	2.5	V
Output Voltage Swing (Vsat – Vdark)	2.0	2.7		
Conversion Gain		3.4		$\mu V/e^-$
Full Well: Res = 1024 Res = 512 Res = 256 Res = 128		800 1600 3200 6400		ke^-
Dynamic Range	66	71		dB
Pixel Non-Uniformity Dark		±0.2	±0.5	%Sat
Photo Response Non-Uniformity		3%	8%	%Sat
Linearity (see Note 2)		0.3	0.5	%
Output due to Dark Current (note 6)		6		mV/s
Fill Factor		100		%Area
Absolute QE at peak (675nm)		60		%
Read Noise (see Note 5)		0.8	1.9	mVrms
Sensitivity(555nm)		6.74		V/lux-s
Recommended Operating Conditions (Note 3)				
Parameter	**Min**	**Typical**	**Max**	**Units**
Supply Voltage	2.8	5.0	5.5	V
Input High Logic Level	V_{DD}-0.6V			V
Input Low Logic Level			0.6	V
Clock Frequency/Pixel Read Rate	1.0	1000	30,000	kHz
Operating Free Air Temperature (T_A)	-20		60	ºC
Relative Humidity, RH, non-condensing	0		85	%

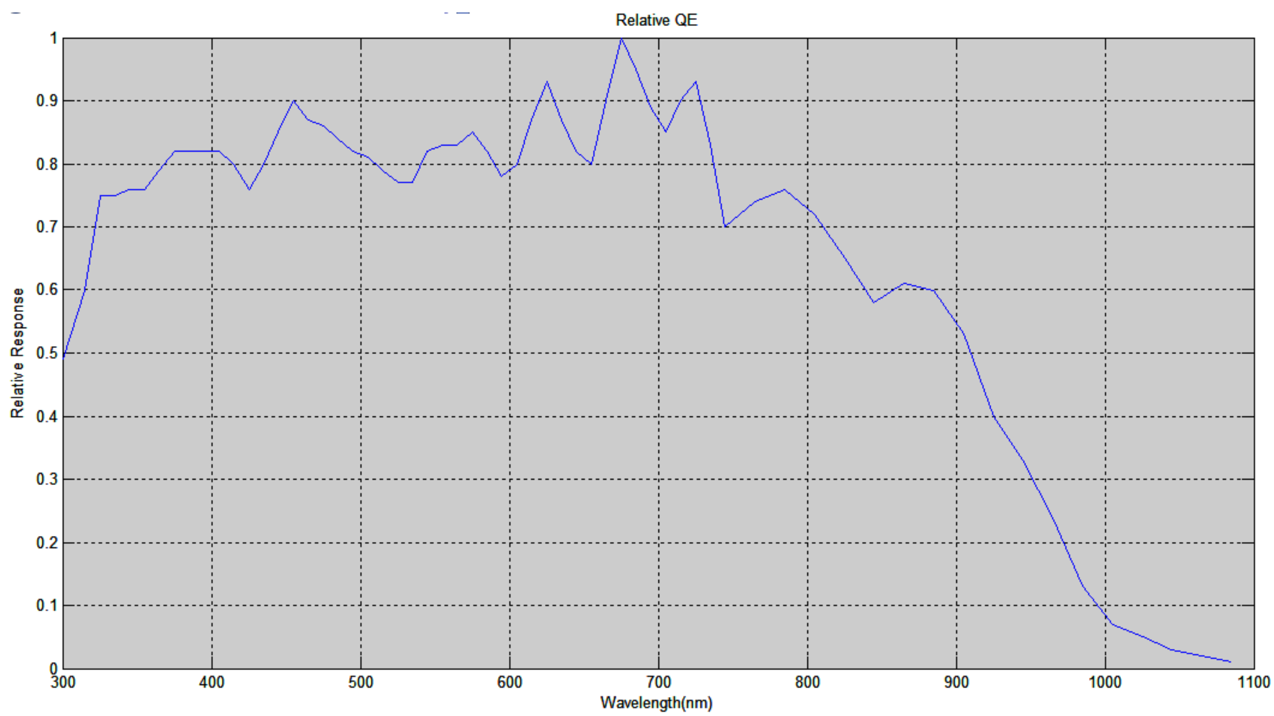
Notes
1. Includes 5k load resistor and measured at dark. Increased speed increases power consumption.
2. Pixel average from 5% - 75% saturation as defined as the difference between the best fit straight line from the actual response from 5% to 75% of Vsat.
3. EO values can change when deviating form the stated test conditions. Operation at higher clock speeds may not be possible at lower supply voltages. MTF degrades with increased clock.
4. At supply voltages less than saturation voltage, Vout is clipped by supply, no load applied.
5. Temporal rms noise @ 1 MHz pixel rate and 500kHz video bandwidth filter applied, values are typical and may vary. Higher Dynamic Range is possible with lower pixel rates and bandwidths.
6. Output due to dark current changes approximately 1.4mV/°C.
7. For characterization information and definitions, see section 'Characterization Criteria' at the end of this specification.

Absolute maximum ratings †

Supply voltage range, V_{DD} . . . . 0 V to 6.0 V
Digital input current range, I_I . . . . –16 mA to 16 mA
Operating case temperature range, T_C (see Note 2) . . . . -20°C to 70°C
Storage temperature range . . . . –40°C to 85°C
Humidity range, RH . . . . 0-100%, non-condensing
Lead temperature 1.5 mm (0.06 inch) from case for 45 seconds . . . . 240°C

† Exceeding the ranges specified under "absolute maximum ratings" can damage the device. The values given are for stress ratings only. Operation of the device at conditions other than those indicated under "recommended operating conditions" is not implied. Exposing the device to absolute maximum rated conditions for extended periods may affect device reliability and performance.

NOTES: 1. Voltage values are with respect to the device GND terminal.
2. Case temperature is defined as the surface temperature of the package measured directly over the integrated circuit.



Note: Data below 300nm not measured, but device is sensitive to 200 nm. The QE peaks at 675nm. Shown for un-encapsulated device.

Resolution Selection

By setting the M0 and M1 inputs as indicated in Table 1, several effective resolutions can be realized. The effective imager length is 7.987mm regardless of the selected resolution. Internally, the device has 1024 pixels. As the resolution decreases the effective pixel area increases as in Table 1. When the resolution is set to 512, the photodiodes of pixels 1 and 2 are averaged and output as a single value, pixels 3 and 4 are averaged and output as a single value, and so on. If set to 256 resolution, then pixels 1 through 4 are averaged and output as a single value, 5 through 8 are averaged and output as a single value, and so on. The internal control logic determines the resolution and always outputs a valid pixel per clock cycle. For example, if the imager is selected for 256-pixel resolution, then only 256 clock cycles are needed to read out the imager once DATA is set. Thus, for lower resolutions higher frame rates are attained with the same clock rate.

Table 1: Resolution Select.

M1	M0	Resolution	Effective Pixel Size
0	0	1024	7.8 x 125µm
0	1	512	15.6 x 125µm
1	0	256	31.2 x 125µm
1	1	128	64.4 x 125µm

Frame Rate, Resolution, and Clock

Frame rate depends on resolution mode selected and clock speed. One pixel is output per clock cycle at any resolution mode so it takes 128 clocks to read out 128 resolution mode, 256 clocks at 256 resolution and so on. Therefore at 2.6MHz clock and at 128 pixel mode, the sensor can output about 20,000 frames per second.

Power Management and Standby Mode

This device incorporates internally controlled power management features and an externally controlled low-power Standby Mode. When resolutions lower than 1024-pixels are selected, internal logic disables the unused amplifiers reducing the power consumption. Utilizing the existing external signals RST and DATA a low-power Standby Mode is possible. When RST and DATA are simultaneously held high the entire imager is put into Standby Mode. In this mode all internal amplifiers are disabled, the internal clocks are stopped and the output amplifier is also disabled. The clock can be held low or high or remain running while the imager is held in standby.

Frame Mode Timing (RM = 0)

In Frame Mode three signals are required for operation not including resolution selection and CLK. These being reset (RST), shutter (SHT) and start data readout (DATA). Both RST and SHT are asynchronous to the system clock, which allows unlimited reset and integration timing resolution.

Standard Timing

The timing relations for Standard Timing are shown in Figure 1 and detailed descriptions are given below. In the VIDEO waveform the 'X Clock Cycles' is determined by the resolution selected. The clock should be 50% duty cycle.

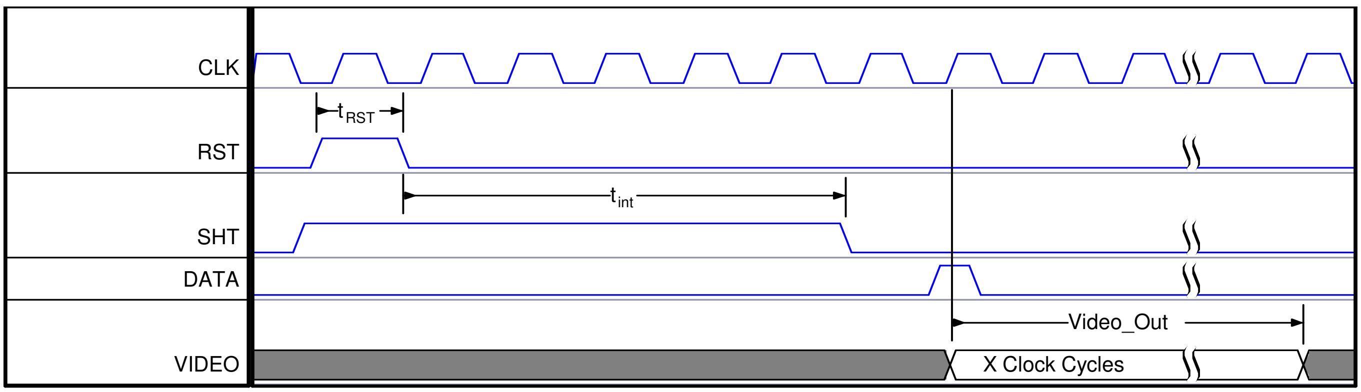


Figure 1: Start of Frame Timing Diagram.

Device Reset:
The pixels are simultaneously reset while the RST and SHT inputs are both held high for at least 200ns, as indicated by t_{RST}. The imager can be held in reset indefinitely by keeping both inputs high. When RST is high the internal clocks to the shift register are disabled and the shift register is held in reset. Once RST goes low the shift register comes out of reset and the clocks begin running.

Integration:
Once RST goes low (while SHT is high), the pixels begin to integrate. Integration continues until SHT goes low as indicated by t_{int}.

Readout:
Readout will begin on the first rising edge of CLK after the DATA input is set high. DATA must be brought low prior to the next rising edge of CLK, otherwise pixel 1 is again output along with pixel 2. See Figure 2 for details. The RST pulse always resets the internal shift register, thus the next pixel to be readout after the first rising edge of CLK when DATA is asserted is the first pixel. The timing details of the DATA pulse are shown below, t_D = 10ns.

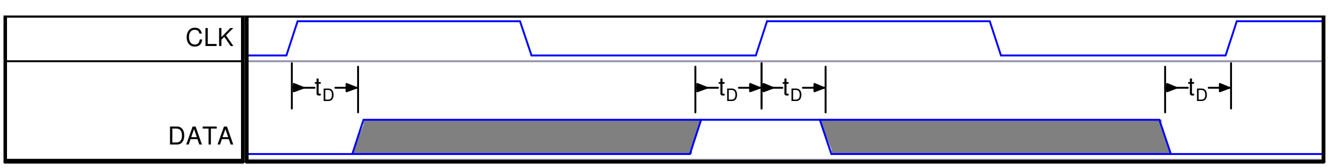


Figure 2: Detailed DATA Pulse Timing Diagram.

Non-Destructive Readout (NDRO)

NDRO mode is similar to the standard mode of operation except that the pixels are readout multiple times for a single integration time. The required signal timings are shown in Figure 3.

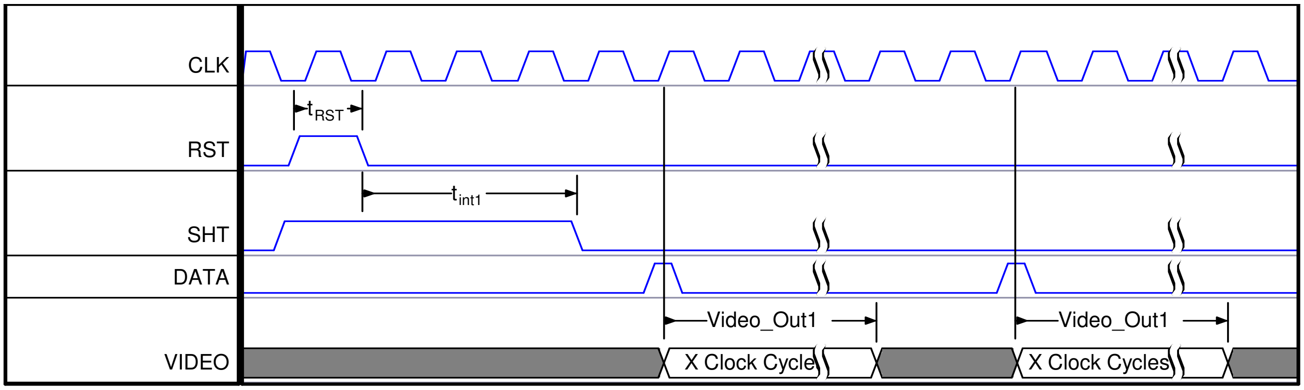


Figure 3: Non-Destructive Readout Timing Diagram.

Dynamic Pixel Reset (DPR) Mode Timing (RM = 1)

In DPR mode the pixels are reset by internal signals, which eliminates the need for using the external reset pin. When operating in DPR mode RST must be held low otherwise the internal logic will be held in reset. However, RST does NOT reset the pixels in DPR mode. Since the pixels are continuously integrating (except the one clock cycle they are being reset) the SHT pin should always be held high. The first frame readout will be invalid because the pixels will have been integrating for an unknown period of time. Valid video will be generated during the second frame. The required signal timings are illustrated in Figure 4.

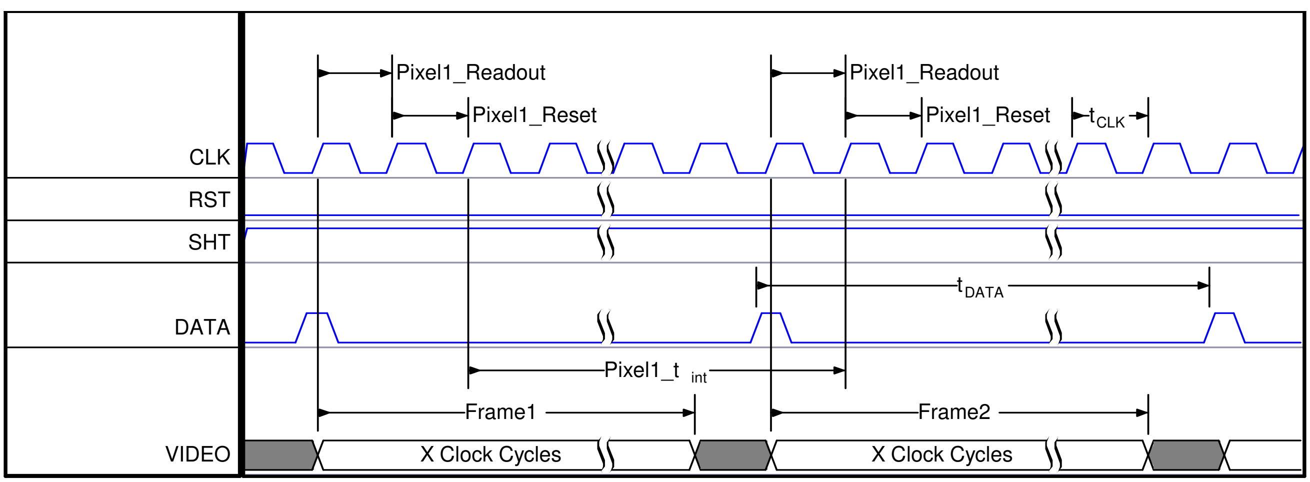
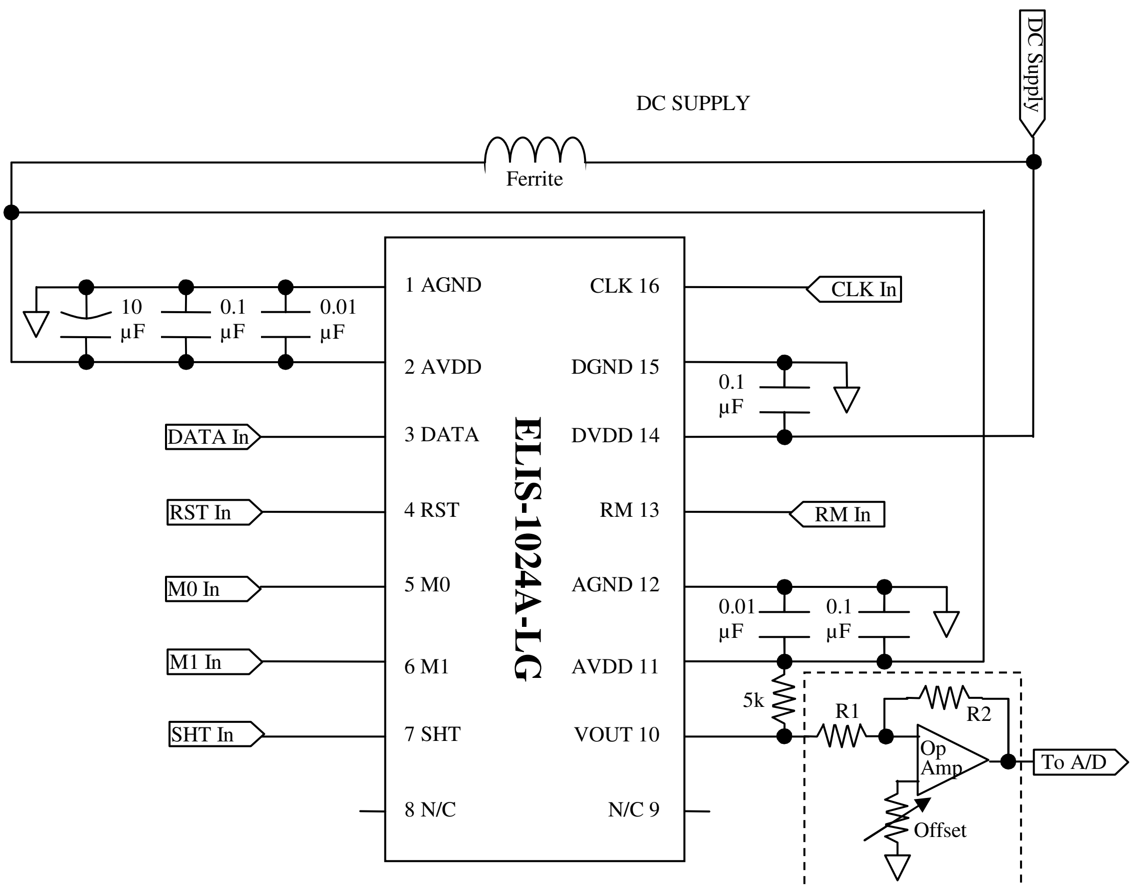


Figure 4: DPR Mode Timing Diagram.

Pixel 1 was used as an example to show the key timing situations. During the first clock cycle after DATA is high pixel 1 is readout. Then while pixel 2 is being readout during the second clock cycle pixel one is being reset. The integration time for pixel 1 then becomes the time between the rising edge of the third clock pulse of Frame 1 to the rising edge of the second clock of Frame 2. In general the integration time is the period of DATA less one clock cycle ($t_{int} = t_{DATA} - t_{CLK}$). In reality the integration time ends when the signal is sampled by the external circuitry.

A one-clock cycle delay between the end of Frame 1 and start of Frame 2 is shown in Figure 4. This delay can be as low as zero clock cycles and as high as desired. There is no restriction to the delay between frames but at very long integration times dark current may become an issue.

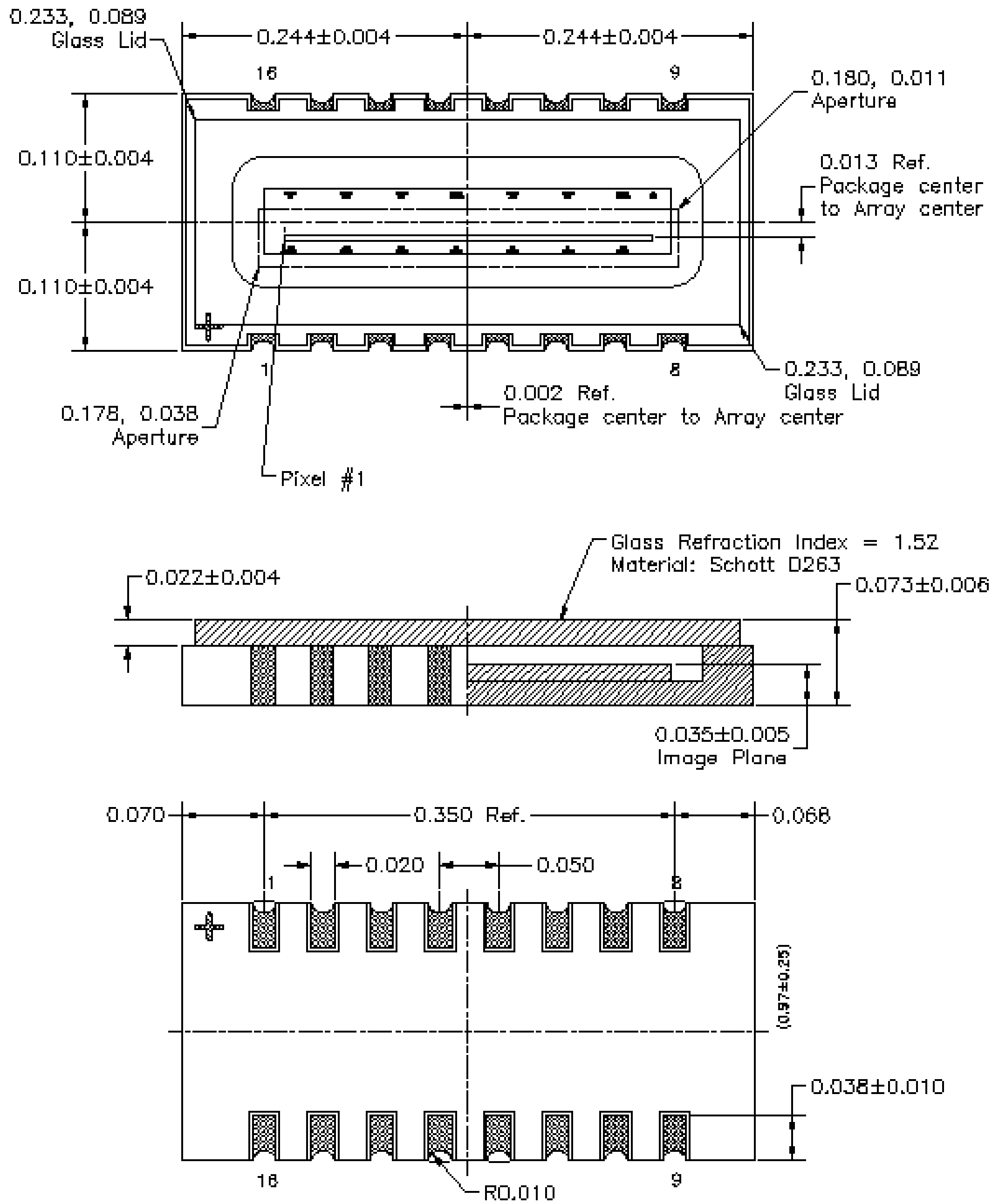
Typical Application Circuit



Optional Gain / Offset Stage.
Typical gain is 3x to 300x for most applications.

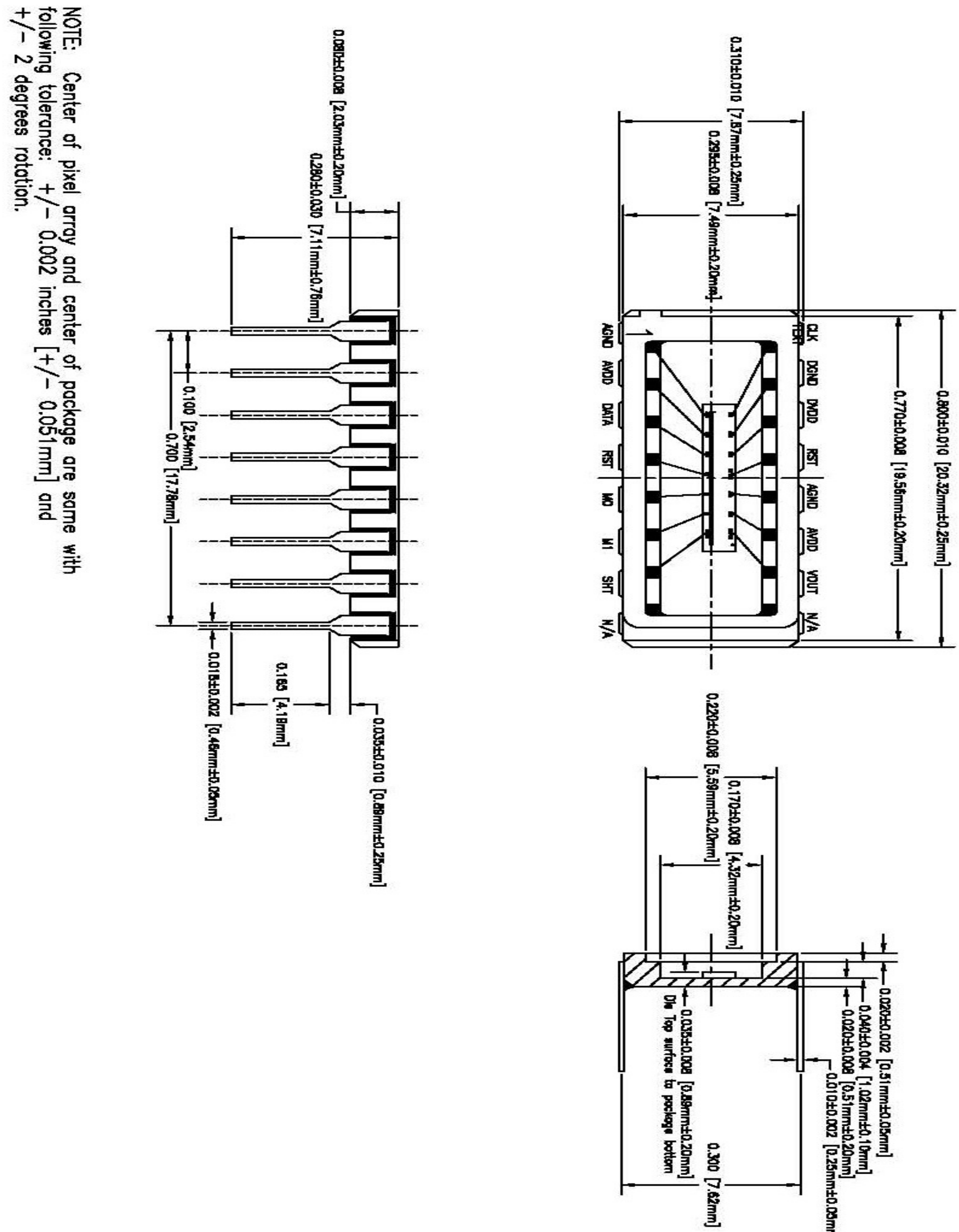
The ELIS-1024 has very high Dynamic Range and Signal to Noise Ratio, thus it is also very sensitive. However external gain may be needed to increase voltage output to match the voltage input range for most A/D converters. The application circuit above shows a simple gain stage for illustration only. See our Application Note titled “Sensitivity vs. Responsivity” for more information. Also see Application Note titled “ELIS-NDRO” describing the use of the Non-Destructive Read capability of the sensor to further increase S/N ratio.

LCC Package Mechanical Information, P/N ELIS-1024A-LG



Units are in inches unless otherwise noted

DIP Package Mechanical Information, P/N ELIS-1024A-D-ES

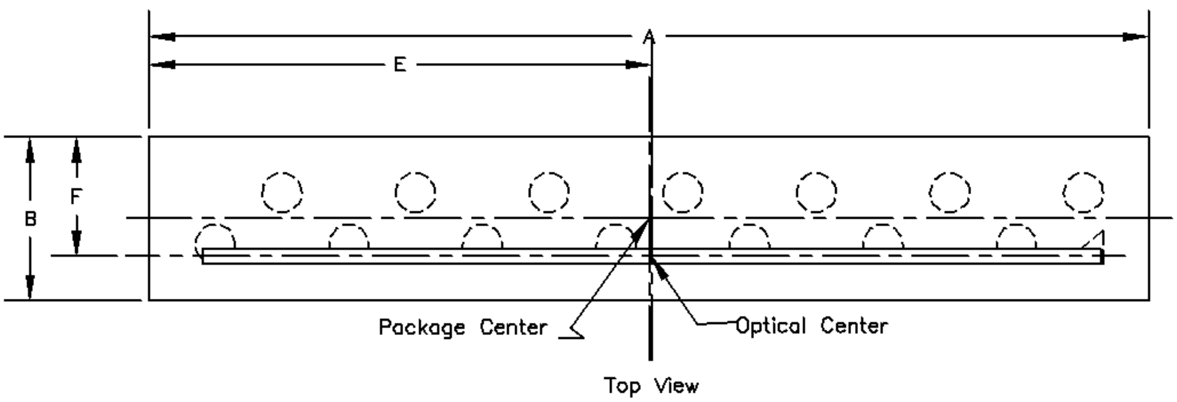


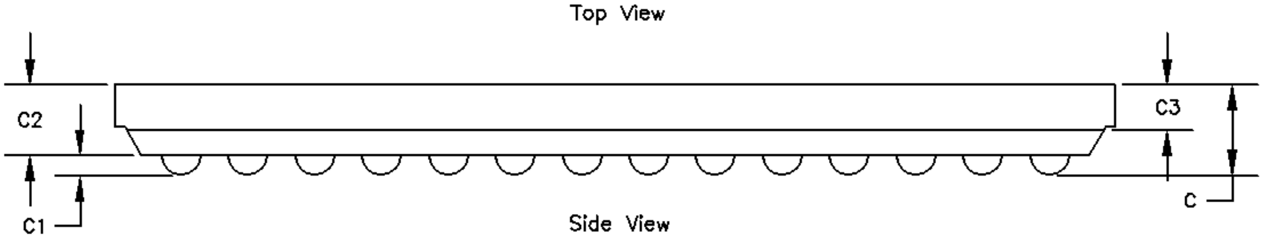
Units are in inches unless otherwise noted

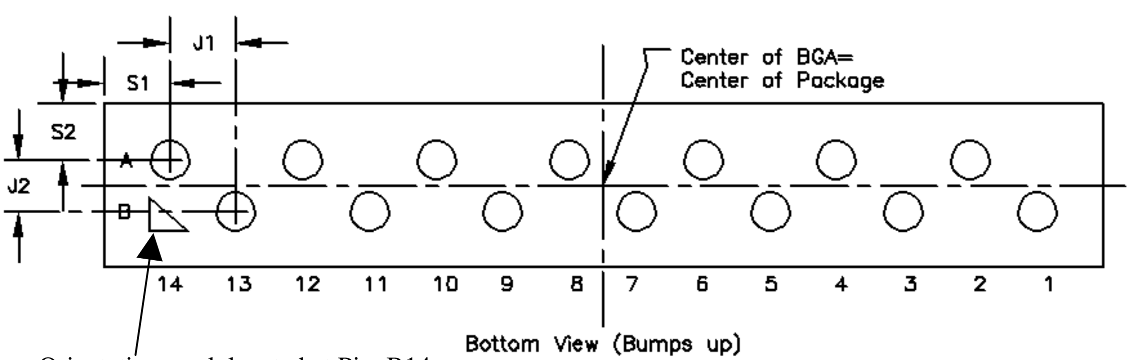
CSP Package Mechanical Information, P/N ELIS-1024-CP-ES

Symbol	Description	Nominal	Min.	Max.
A	Package Length X	8887	8862	8912
B	Package Width Y	1457	1432	1482
C	Package Height Z	810	750	870
C1	Ball Height	180	150	210
C2	Package Body Thickness	630	595	665
C3	Thickness of Glass Surface to Die Surface	405	385	425
D	Ball Diameter	350	320	380
N	Total Pin Count	14		
N1	Pin Count X Axis	14		
N2	Pin Count Y Axis	2		
J1	Pin Pitch X Axis	594		
J2	Pin Pitch Y Axis	456		
S1	Edge to Pin Center Distance X	581	551	611
S2	Edge to Pin Center Distance Y	501	471	531
E	Edge to Optical Center Distance X	4465	4440	4490
F	Edge to Optical Center Distance Y	1065	1040	1090
OX	Optical Array Length X	7987		
OY	Optical Array Height Y	125		

Dimensions are in Microns







Orientation mark located at Pin B14

ORDERING INFORMATION

These devices are offered in several packaging options as follows;

ELIS-1024A-LG Leadless Chip Carrier (LCC).
ELIS-1024A-D-LG-ES 16 pin ceramic dual inline package (DIP) without window.
ELIS-1024A-CP-ES – Chip Scale Package (μBGA)
ELIS-1024A-G – Known Good die on wafer

Note: ES designates Engineering Sample Grade

Contact Panavision Imaging, LLC or your local authorized representative for pricing and availability.

Characterization Criteria

Characterization measurements are guaranteed by design and are not tested for production parts. Unless otherwise specified, the measurements described herein are characterization measurements.

Pixel Clock Frequency

The pixel clock frequency is the frequency at which adjacent pixels can be reliably read.

Full Well

Full well (or Saturation Exposure) is the maximum number of photon-generated and/or dark current-generated electrons a pixel can hold. Full well is based on the capacitance of the pixel at a given bias. Full well is determined by measuring the capacitance of all pixels for the operational bias. In reality, the pixel analog circuitry will limit the signal swing on the pixel, so full well is defined as the number of electrons that will bring the output to the specified saturation voltage.

Quantum Efficiency

Quantum Efficiency is a measurement of the pixel ability to capture photon-generated charge as a function of wavelength. This is measured at 10nm increments over the wavelength range of the sensor typically over the range 300 to 1100 nm. Measurements are taken using a stable light source that is filtered using a monochromator. The exiting light from the monochromator is collimated to provide a uniform flux that overfills a portion of the sensor area. The flux at a given wavelength is measured using a calibrated radiometer and then the device under test is substituted and its response measured.

Linearity

Linearity is an equal corresponding output signal of the sensor for a given amount of photons incident on the pixel active area. Linearity is measured by plotting the imager transfer function from dark to saturation and fitting a 'best fit' straight line from 5% to 75% of saturation. The maximum peak-peak deviation of the output voltage from the 'best fit' straight line is computed (E_{pp}) over the fitting range. Linearity (L) is then computed as shown below where V_{FS} is the full-scale voltage swing from dark to saturation measured with sensor gain at 0.0 dB.

$$L = \left(1 - {E_{pp}}/{V_{FS}}\right) \times 100\%$$

Average Dark Offset

The 'dark offset' is the voltage proportional to the accumulated electrons for a given integration period, that were not photon generated i.e. dark current. There are a few sources in CMOS circuits for the dark current and the dark current levels will vary even for a given process. Dark offset is measured as the delta in output voltage from integration time 0 sec. to 1.0 sec with no light at T_A = 24°C.

Read Noise

Read noise is the temporal or time variant noise in the analog signal due to thermal noise in the analog path. Read noise does not include spatial noise such as fixed pattern noise (FPN). Read noise is measured at the output of the imager with proper loading and bandwidth filtering at 50% saturation and is calculated using the following;

$$TemporalRMSnoise = \sqrt{\frac{1}{1024}\sum_{i=1}^{1024}\sigma_i^2}$$

Image Lag

Image lag is the amount of residual signal in terms of percent of full well on the current frame of video after injecting the previous frame of video. Image lag is measured by illuminating an ROI to 50% of saturation for one frame and then rereading those pixels for the next and subsequent frames without light exposure. Any remaining residual signal will be measured and recorded in terms of percent of full well.

Dynamic Range

Dynamic range is determined by dividing the full-scale output voltage swing by the root mean squared (rms) temporal read noise voltage and expressed as a ratio or in decibels.

$$DR = 20\log\left[{V_{FS}}/{e_n}\right]$$

Modulation Transfer Function (MTF)

MTF is a measure of the imager's ability to sense and reproduce contrast as a function of spatial frequency. MTF is measured by illuminating a sensor with a Davidson Optronics PR-10 squarewave burst pattern having 11 discrete spatial frequencies. Therefore, strictly speaking, we are measuring Contrast Transfer Function (CTF) since squarewave targets are easier to obtain and work with. Images are captured with the input pattern oriented both horizontally and vertically and saved as 8-bit images. The sensor's response is derived from the captured images as shown below where M is the measured modulation and S_{MAX}, S_{MIN} are the digital numbers (DN) associated with the spatial frequency under evaluation.

$$M \equiv \frac{S_{MAX} - S_{MIN}}{S_{MAX} + S_{MIN}}$$

$$MTF \approx CTF \equiv M_{output} / M_{input}$$

Dark Signal Non-Uniformity (DSNU))

Dark signal non-uniformity (DSNU), also known as Fixed Pattern Noise (FPN), is a measure of pixel-to-pixel variation when the array is in the dark. It is primarily due to dark current differences, reset noise and synchronous timing effects. It is a signal-independent noise and is additive to the other noise powers. The FPN associated with the sensor consists of variations in pixel offset. Offset variations within any pixel are inherently low due to the ACS technology. Similarly, gain related FPN is almost non-existent due the ACS technology. FPN is measured as a peak-to-peak variation along a line of video averaged to remove temporal noise.

Photo-Response Non-Uniformity (PRNU)

Photo Response Nonuniformity is pixel-to-pixel variation in the response of an array to a fixed-intensity light.

$$PRNU \equiv \Delta X / Xm$$

Where Xm is the average of the total signal outputs and ΔX is the maximum deviation from Xm under uniform lighting and measured at about 50% of Vsat.

Movie Mode

Choose movie mode to shoot **h**igh-**d**efinition (HD) or slow-motion (📖 40) movies using the movie-record button.

> **The [no-REC] Icon**
> A [no-REC] icon indicates that movies can not be recorded.
>
> **Available Settings**
> For information on the options available in movie mode, see page 49.

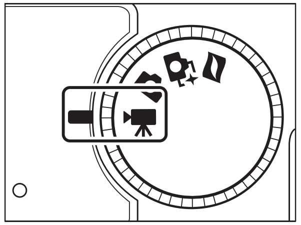
HD Movies

Record movies with sound at an aspect ratio of 16 : 9.

1 Select movie mode.

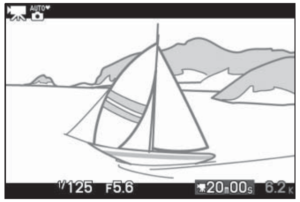
Rotate the mode dial to [movie]. An HD movie crop with an aspect ratio of 16 : 9 will appear in the display.

Mode dial



2 Frame the opening shot.

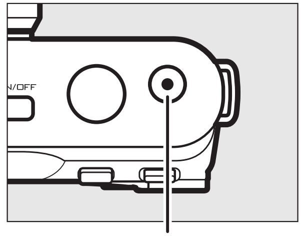
Holding the camera as shown on page 22, frame the opening shot with your subject in the center of the display.



> **Exposure Mode**
> By default, the camera automatically chooses a scene mode appropriate to the subject (automatic scene selection; 📖 21).
>
> **See Also**
> See page 133 for information on adding fade in/fade out effects. Frame size and frame rate options are described on page 116.

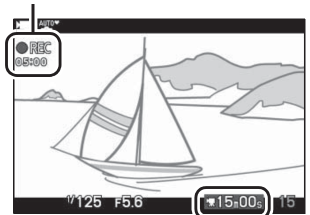
3 Start recording.

Press the movie-record button to begin recording. A recording indicator, the time elapsed, and the time available are displayed while recording is in progress.



Movie-record button

Recording indicator/ Time elapsed



Time available

> **Audio Recording**
> Be careful not to cover the microphone and note that the built-in microphone may record sounds made by the camera or lens. By default, the camera focuses continuously; to avoid recording focus noise, select a focus mode of **AF-S** (📖 137). The **Movie sound options** item in the shooting menu offers sensitivity and wind noise options for the built-in microphone (📖 134).

4 End recording.

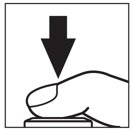
Press the movie-record button again to end recording. Recording will end automatically when the maximum length is reached (📖 116), the memory card is full, another mode is selected, the lens is removed, or the camera becomes hot (📖 xvi).

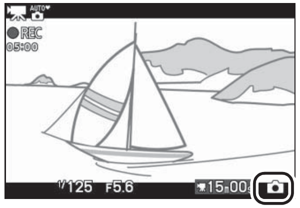
> **Maximum Length**
> HD movies can be up to 4 GB in size and 20 minutes in length (for more information, see page 116); note that depending on memory card write speed, shooting may end before this length is reached (📖 160).

> **Exposure Lock**
> In exposure modes other than [SCENE] **Scene auto selector**, exposure will lock while the AE-L (multi selector up) button is pressed (📖 118).

Taking Photographs During HD Movie Recording

Press the shutter-release button all the way down to take a photograph without interrupting HD movie recording. Photographs taken during movie recording have an aspect ratio of 16 : 9.



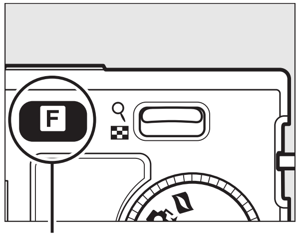


> **Taking Photographs During Movie Recording**
> Up to 15 photographs can be taken with each movie shot. Please note that photographs can not be taken with slow-motion movies.

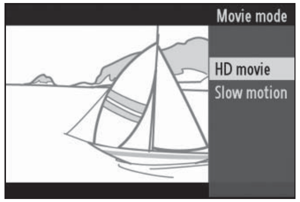
Choosing the Movie Type

To choose between high definition and slow motion recording, press F and use the multi selector and OK button to choose from the following options:

- **HD movie**: Record movies in HD.
- **Slow motion**: Record slow-motion movies (🕮 40).



F button



> **Recording Movies**
> Flicker, banding, or distortion may be visible in the displays and in the final movie under fluorescent, mercury vapor, or sodium lamps or if the camera is panned horizontally or an object moves at high speed through frame (flicker and banding can be reduced in HD movies by choosing a **Flicker reduction** option that matches the frequency of the local AC power supply; 🕮 153). Bright light sources may leave after-images when the camera is panned. Jagged edges, color fringing, moiré, and bright spots may also appear. When recording movies, avoid pointing the camera at the sun or other strong light sources. Failure to observe this precaution could result in damage to the camera's internal circuitry.

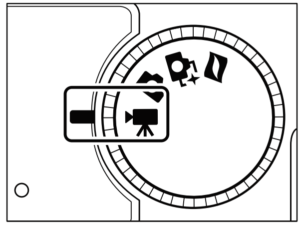
Slow Motion

Record silent movies with an aspect ratio of 8 : 3. Movies are recorded at 400 fps and play back at 30 fps.

1 Select movie mode.

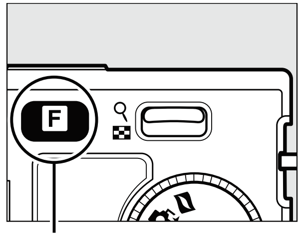
Rotate the mode dial to 🎥.

Mode dial



2 Select slow-motion mode.

Press the F button and use the multi selector and OK button to select **Slow motion**. A slow-motion movie crop with an aspect ratio of 8 : 3 will appear in the display.



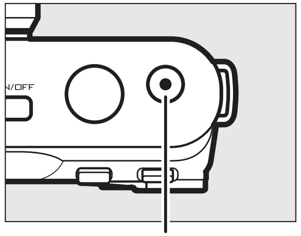
F button

3 Frame the opening shot.

Holding the camera as shown on page 22, frame the opening shot with your subject in the center of the display.

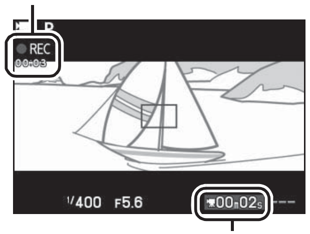
4 Start recording.

Press the movie-record button to begin recording. A recording indicator, the time elapsed, and the time available are displayed while recording is in progress. The camera focuses on the subject at the center of the display; face detection (📖 23) is not available.



Movie-record button

Recording indicator/ Time elapsed



Time available

5 End recording.

Press the movie-record button again to end recording. Recording will end automatically when the maximum length is reached, the memory card is full, another mode is selected, the lens is removed, or the camera becomes hot (📖 xvi).

> **Maximum Length**
> Up to 5 seconds or 4 GB of footage can be recorded; note that depending on memory card write speed, shooting may end before this length is reached (📖 160).

> **Exposure Mode**
> The default exposure mode for slow-motion movie recording is **P Programmed auto** (📖 108). **SCENE Scene auto selector** is not available in slow-motion movie mode.
>
> **See Also**
> Frame rate options are described on page 116.

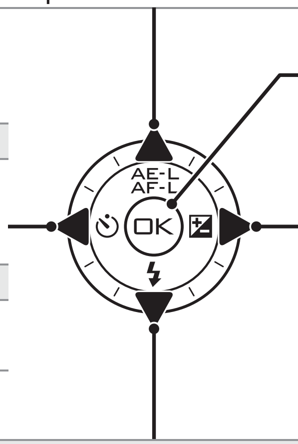
The Multi Selector

The multi selector and ⓞ button are used to adjust settings and navigate the camera menus (📖 9).

Settings: AE-L AF-L
Lock exposure (📖 118) and/or focus (📖 143).
Menu navigation: ▲
Move cursor up.

Select highlighted item.

Settings: ⏱
View self-timer/ remote-control menu (📖 53).
Menu navigation: ◀
Return to previous menu.

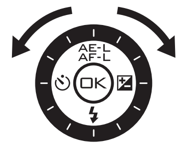


Settings: ☒
View exposure compensation menu (📖 56).
Menu navigation: ▶
Select highlighted item or display sub-menu.

Settings: ϟ
View flash mode menu (📖 58).
Menu navigation: ▼
Move cursor down.

Note: You can also highlight items by rotating the multi selector.

> **The Multi Selector**
> In this manual, the ▲, ▶, ▼, and ◀ symbols are used to represent up, right, down, and left on the multi selector. Items can be highlighted by rotating the multi selector as shown at right.



More on Photography

Self-Timer and Remote Control Modes

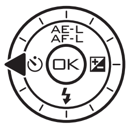
The self-timer and optional ML-L3 remote control (📖 158) can be used to reduce camera shake or for self-portraits. The following options are available:

Off	Self-timer and remote control off. The shutter is released when the camera shutter-release button is pressed.
10s **10 s**	The shutter is released 2, 5, or 10 seconds after the shutter-release button is pressed all the way down. Choose **2 s** to reduce camera shake, **5 s** or **10 s** for self-portraits.
5s **5 s**	
2s **2 s**	
2s **Delayed remote**	The shutter is released 2 s after the shutter-release button on the optional ML-L3 remote control is pressed.
Quick-response remote	The shutter is released when the shutter-release button on the optional ML-L3 remote control is pressed.

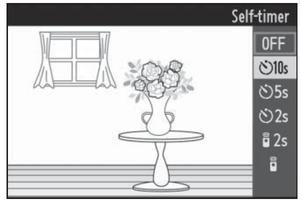
Before Using the Remote Control
Before using the remote control for the first time, remove the clear plastic battery-insulator sheet.

1 Mount the camera on a tripod.
Mount the camera on a tripod or place the camera on a stable, level surface.

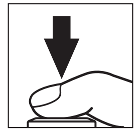
2 Display self-timer options.
Press ◀ (⏲) to display self-timer options.

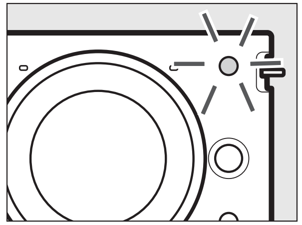


3 Select the desired option.
Use the multi selector to highlight the desired option and press ⊛.



4 Frame the photograph and shoot.
Self-timer mode: Press the shutter-release button halfway to focus, and then press the button the rest of the way down. The self-timer lamp will start to blink and a beep will begin to sound. Two seconds before the photo is taken, the lamp will stop blinking and the beeping will become more rapid.





Remote control mode: Aim the ML-L3 at the infrared receiver on the camera (📖 2) and press the ML-L3 shutter-release button (stand at a distance of 5 m/16 ft or less). In delayed remote mode, the self-timer lamp will light for about two seconds before the shutter is released. In quick-response remote mode, the self-timer lamp will flash after the shutter has been released.