

Shad-o-Box™ 1024

X-Ray Camera



Key Features:

- 50 mm (2") square active area
- Over one million pixels
- 10 lp/mm (48 μ m) resolution
- 12 or 14-bit digital video output
- Energy range from 10 to 160 kV
- Small, convenient form factor
- Standard frame grabber interface
- Ready-to-run software and drivers

The Shad-o-Box™ 1024 x-ray camera is a stand-alone, high-resolution radiation imaging device complete with a parallel digital interface. The large 49.2 mm by 49.2 mm sensing area consists of a 1024 by 1024 pixel photodiode array sensor with 48 μ m pixel spacing. An integral phosphor screen shields the sensor from ambient light and converts incident x-rays or energetic particles to visible light that is sensed by the silicon photodiodes. Two models for low x-ray energies (10-50 kV) and an extended energy range (10-160 kV) can be used in a wide range of applications including medical diagnostics, industrial inspection (NDT) and scientific imaging.

Overview:

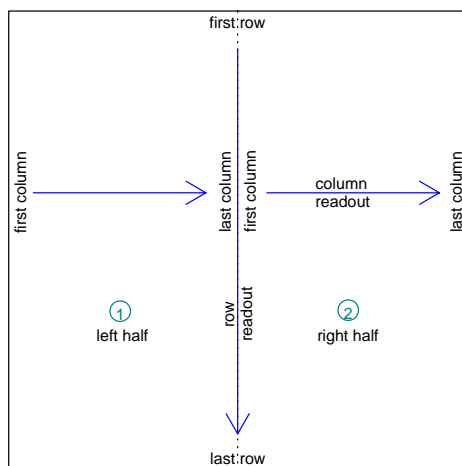
The Shad-o-Box™ 1024 x-ray camera is a complete detection system for high-resolution radiation imaging. The heart of the Shad-o-Box camera is a two-dimensional photodiode array containing 1024 by 1024 pixels on 48 μm centers. A Gd₂O₂S scintillator screen, placed in direct contact with the photodiode array, converts incident x-ray photons to light, which in turn is detected by the photodiodes. A carbon-fiber window shields against ambient light and protects the sensitive electronics from accidental damage.

The analog signal from the photodiode sensor is digitized to 12-bit (or optionally 14-bit) resolution in two parallel A/D channels, and then interleaved for maximum transmission speed across a high-speed parallel digital interface. The interface consists of a 68-pin mini-D (SCSI-3) receptacle and uses the LVDS (EIA-644) signaling standard for low power consumption and transmission lengths up to 30m. Pixel clock, line enable and frame enable signals are available at the connector to facilitate acquiring the image data with a standard digital frame grabber. An RS-422 option is also available.

The standard version of the Shad-o-Box 1024 camera delivers 4000:1 dynamic range (defined as the maximum signal divided by the read noise) at a maximum frame rate of 2.7 frames per second. A special high-gain version doubles the sensitivity of the analog front end, at the expense of a slight increase in noise and image non-uniformity. All models operate from a standard +6.5V desktop power supply and consume less than six Watts of power.

Readout Sequence:

The image area of the Shad-o-Box sensor is scanned through two parallel channels. As indicated in the figure below, the row scan starts at the top of the active area and scans toward the bottom. Each line is scanned in two sections, starting at the leftmost and center columns and moving towards the right. The two sections are scanned in parallel and then interleaved for transmission. The data must be deinterlaced in software to restore the image.



A two-pixel gap separates the left and right halves of the active area. This space should be taken into account when reconstructing the image from the data stream. (Please refer to Rad-ikon Apnote AN03 for more details on image correction.)

Specifications:

Detector Specifications	Standard	Hi-Res	Units
Typ. dark current (23°C) ⁽¹⁾	10 / 20 [#]	40 / 80 [#]	ADU/s ⁽²⁾
Read noise (rms)	~ 1	~ 2	ADU
Dynamic range	4000:1	8000:1	
Digitization	12	14	bits
Conversion gain	500/250 [#]	125 / 62 [#]	elec/ADU
Saturation signal	2.0/1.0 [#]	2.0/1.0 [#]	x10 ⁶ elec.
Typ. sensitivity ⁽³⁾	25 / 50 [#]	100/200 [#]	ADU/mR
Readout period	367	367	ms
Max. frame rate	2.7	2.7	Hz
Output data rate	3.0	3.0	MHz

⁽¹⁾ dark current doubles approx. every 8°C [#] high-gain option

⁽²⁾ ADU = Analog-Digital Unit = 1 LSB (Least Significant Bit)

⁽³⁾ EV model, 50kVp W source, 0.5mm Al filter, Min-R 2190 scintillator

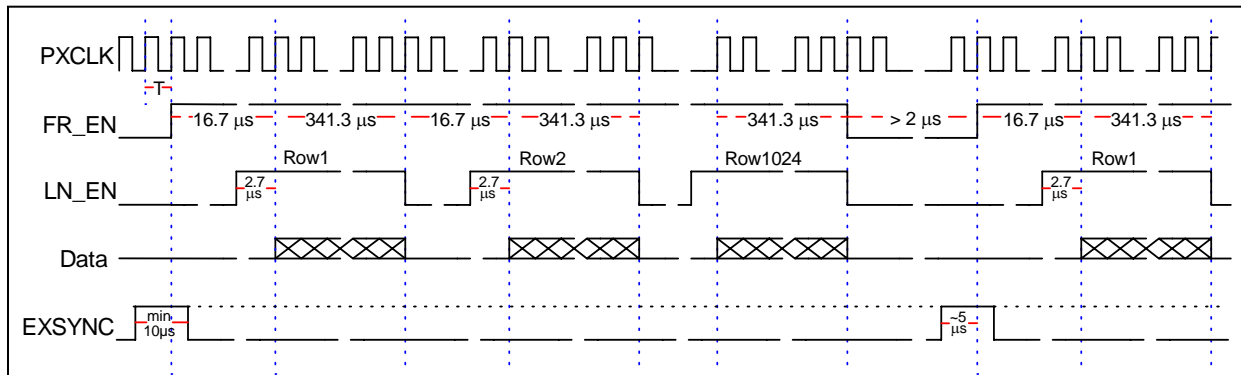
Camera Specifications	LVDS	RS-422	Units
Typical supply voltage	6.5	6.5	Volts
Supply voltage range	6.0 to 8.0	6.0 to 8.0	Volts
Maximum supply current	350	750	mA
Typical power dissipation	< 3	< 6	Watts
Parallel digital interface	EIA-644	RS-422	
SMA connector interface	TTL	TTL	

General Specifications	All Versions	Units
Operating Temperature	0 to 50	°C
Storage Temperature	-25 to +85	°C
Humidity (non-condensing)	10 to 80	% R.H.
Weight	1.5	kg

Camera Timing:

The camera frame rate can be controlled through the external frame sync inputs on either the parallel interface (EXSYNC) or the separate SMA receptacle. If these inputs are pulled high (SMA not connected) the camera will run continuously at its maximum frame rate of 2.7 fps. If either one of the frame sync inputs is pulled low, the camera controller will wait for a rising edge on this input before starting the next frame readout. To avoid conflicts, only one of these inputs should be used at a time. In a typical configuration, the EXSYNC input will be controlled by a timer on the frame grabber board. The timer should be programmed to supply pulses at regular intervals to prevent saturation of the photodiodes.

The digital data on the parallel interface are valid when the pixel clock (PXCLK) is high. To minimize transmission errors, the data should be sampled on its falling edge. The line enable signal (LN_EN) goes high eight clock cycles before the first valid pixel. It is low for 42 pixel clock cycles during the horizontal blanking interval. It is also low for a minimum of 48 cycles between frames. Frame enable (FR_EN) goes low during the vertical blanking interval to signal the beginning of a new frame. This signal is also available on one of the SMA connectors and can be used to synchronize external events to the camera.



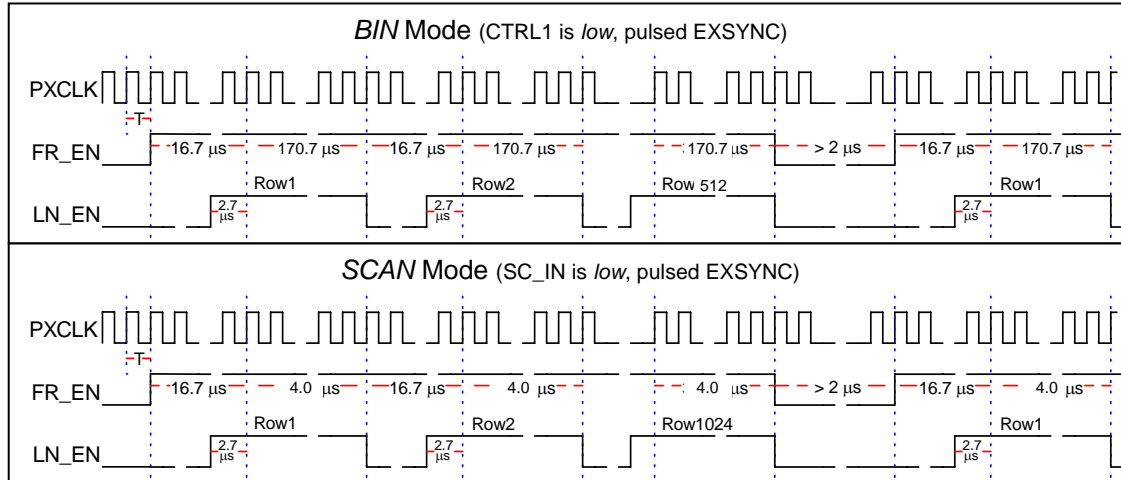
Signal	Parameter	Value	Unit
EXSYNC	min. pulse width	10	μs
	max. pulse width	$365 / 95^{\#} / 20^{\#\#}$	ms
	delay to FR_EN rising edge (typ.)	5	μs
FR_EN	high period (frame active)	$366.6 / 95.9^{\#} / 21.2^{\#\#}$	ms
	low period (EXSYNC high)	2	μs
	low period (EXSYNC low)	until next edge on EXSYNC	
	delay to LN_EN rising edge	14	μs
LN_EN	high period (line active)	$344.0 / 173.3^{\#} / 6.7^{\#\#}$	μs
	low period (between lines)	14	μs
	low period (between frames)	$14\mu s + \text{FR_EN low period}$	
PXCLK	period (T)	333.3	ns
	duty cycle	50	%

[#]BIN Mode (CTRL1 input low)

^{\#\#}SCAN Mode (SC_IN input low)

Camera Timing (cont.):

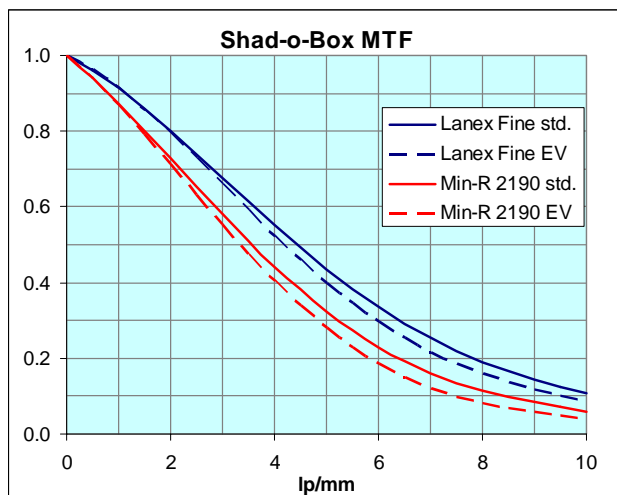
The binning (CTRL1) and fast scan (SC_IN) control inputs offer additional functionality in the camera. The bin mode (CTRL1 *low*) causes the readout to skip every other row and column. This shortens the readout time and raises the maximum frame rate of the camera to 10.4 fps. The resulting sub-sampled image contains 512 columns by 512 rows.



A *low* level on the SC_IN input puts the camera into a rapid-readout mode in which only the first six pixels of each sensor row are read. In this mode it is possible to scan all 1024 rows of the sensor in just 21 ms. This feature can be used to rapidly reset the dark signal prior to an exposure.

Resolution:

The intrinsic resolution of the Shad-o-Box detector is 48 μm , which corresponds to just over 10 line pairs per mm. The actual Modulation Transfer Function (MTF) for two different scintillators is shown in the graph below. A thicker phosphor screen will produce more signal, but at the expense of high-frequency contrast. Please refer to our appnote AN07 for more information on scintillator performance and tradeoffs.



Ordering Information:

Shad-o-Box cameras have two image quality grades (Standard and Premium), and can be ordered either with a Kodak Min-R[®] 2190 or Lanex[®] Fine scintillator. Additional scintillators may be available by special order.

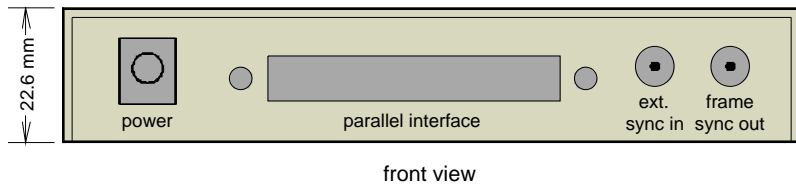
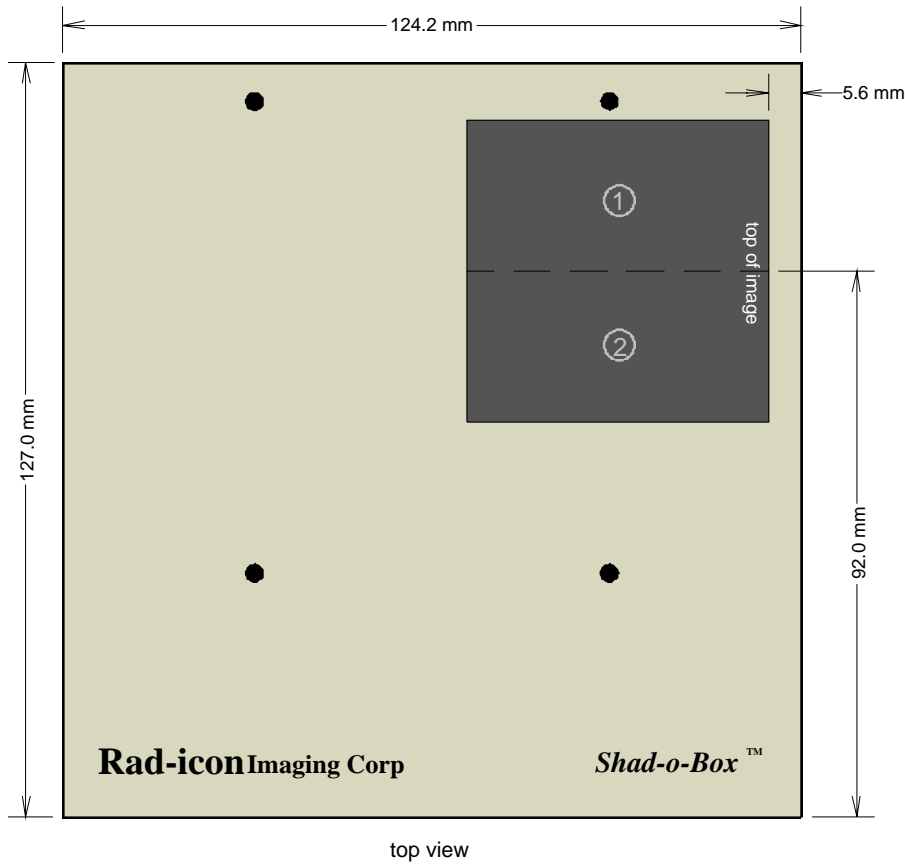
All cameras ship with a universal-input power supply (90-264V, 50-60Hz) and power cord, a software CD, and manual. A frame grabber and data cable must be ordered separately.

When ordering, please specify the type of power cord and any optional features such as high-gain, hi-res (14-bit) or RS-422 as needed.

P/N	Description
SB1011	Shad-o-Box 1024 (10-50 kV)
SB1065	Shad-o-Box 1024 EV (10-160 kV)
-01	Premium Grade ⁽¹⁾ , Min-R 2190
-02	Standard Grade ⁽²⁾ , Min-R 2190
-03	Premium Grade, Lanex Fine
-04	Standard Grade, Lanex Fine

⁽¹⁾ no line defects ⁽²⁾ up to three line defects

Mechanical Dimensions:



Data Connector Pinout:

Signal	Description	I/O	+pin#	-pin#
D15	Data Bit 15 (tied low)	O	2	36
D14	Data Bit 14 (tied low)	O	3	37
D13	Data Bit 13 (MSB)	O	4	38
D12	Data Bit 12	O	5	39
D11	Data Bit 11	O	6	40
D10	Data Bit 10	O	7	41
D9	Data Bit 9	O	8	42
D8	Data Bit 8	O	9	43
D7	Data Bit 7	O	10	44
D6	Data Bit 6	O	11	45
D5	Data Bit 5	O	13	47
D4	Data Bit 4	O	14	48
D3	Data Bit 3	O	15	49
D2	Data Bit 2 ⁽¹⁾	O	16	50
D1	Data Bit 1 ⁽²⁾	O	19	53
D0	Data Bit 0 (LSB) ⁽²⁾	O	20	54
FR_EN	Frame (vert.) Sync	O	25	59
LN_EN	Line (hor.) Sync	O	26	60
PXCLK	Pixel Clock	O	29	63
EXSYNC	Ext. Frame Sync	I	30	64
SC_IN	Fast Scan Control	I	23	57
SC_OUT	(rsrvd for future use)	O	22	56
CTRL1	Binning Control	I	31	65
CTRL2	(rsrvd for future use)	I	32	66
GND	Signal Ground		pins 1,12,34,35,46,68	

Note: Camera inputs (I) must be tied to logic "high" if not in use.

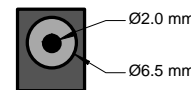
⁽¹⁾ LSB in 12-bit model ⁽²⁾ tied low in 12-bit model

Power Connector:

DC power jack, 2 mm center pin

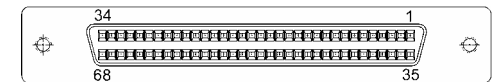
center pin:
6.5 VDC

outside:
ground



Data Connector:

68-pin mini-D (SCSI-3) receptacle



mating connector: AMP 749621-7 (or equiv.)
shell: AMP 786152-3 or 750752-1 (jackscrews)