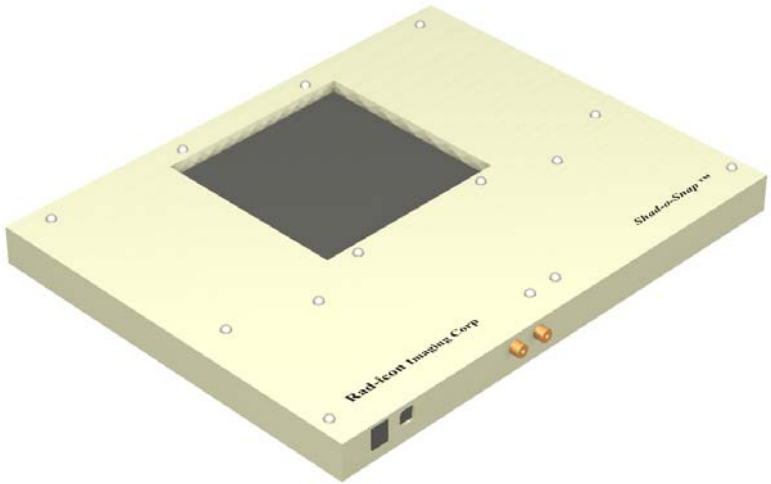
Shad-o-Snap X-Ray Camera
Hardware Manual

P/N 1091 Rev. 03

1. Introduction

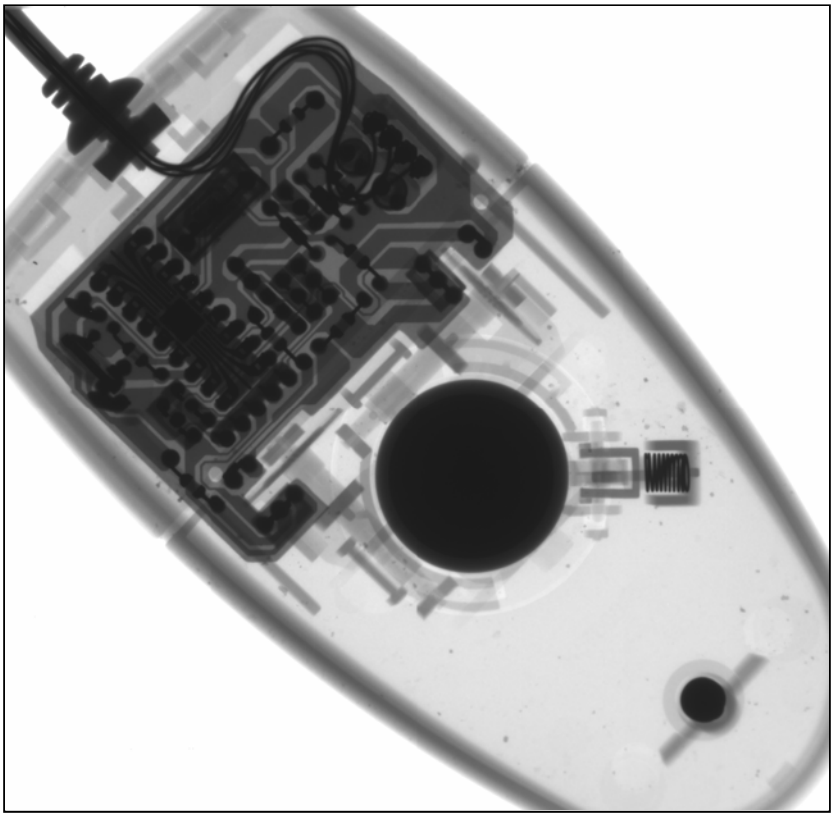
The Shad-o-Snap x-ray camera is a complete, stand-alone x-ray imaging device featuring "smart" microprocessor-controlled camera electronics and a convenient USB interface. The plug-and-play interface allows easy control of camera features such as integration time settings, offset correction and image retrieval. Typical uses of the Shad-o-Snap camera include a wide range of applications such as industrial, biomedical and scientific x-ray imaging.

At the heart of each Shad-o-Snap camera is a large-area high-resolution CMOS detector built from a mosaic of Rad-icon's RadEye1 photodiode array sensors. 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. The Shad-o-Snap camera also includes electronics to digitize the video signal, a camera controller to generate the appropriate timing signals, and a microprocessor to manage the USB interface and advanced camera functions.



Shad-o-Snap 4K

This manual provides an overview of the Shad-o-Snap installation process and the operation of the camera. Each Shad-o-Snap camera ships with our CameraConsole application, which provides a user-friendly interface for communicating with the camera. Images can also be acquired using Rad-icon's ShadoCam software (for 16-bit raw integer files) or exported to a TIFF viewer (for 8-bit TIFF files). All camera timing signals are internally generated, and for basic imaging operations there is no need to synchronize the camera with a frame grabber or other hardware. However, a separate frame sync input and output are provided in case you wish to monitor the camera timing or control it with an external trigger (see Section 4).



2. Camera Installation

The Shad-o-Snap camera operates from a single 6-8 Volt DC power supply. The maximum power dissipation is up to 6 Watts, depending on the camera model. Each camera ships with a universal 6.5 Volt desktop power supply, but the Shad-o-Snap can also be operated from a battery supply (available separately). To start the camera, connect the DC power plug from the power supply to the receptacle on the camera's front panel. Plug the power supply into a grounded wall outlet or power strip. The camera will initialize and start up automatically within a few seconds. To turn off the camera, unplug the power supply or use the switch on your power strip. The camera can be reset at any time simply by cycling the power supply. Any images stored in the camera's on-board memory will be lost as soon as the power is turned off.

The Shad-o-Snap x-ray camera uses a USB interface in order to communicate with a computer. Connect a USB device cable between the USB port on the camera front panel and an unused USB port on your computer. A USB device cable has a "Series A" plug on one end and a "Series B" device plug on the other. A shielded cable for either the USB 1.1 or USB 2.0 standard is recommended. USB cables are readily available in lengths up to 15 feet (5 m). Longer connections are possible by stringing up to five cable segments together with repeater hubs in between.

The USB firmware inside the Shad-o-Snap camera uses drivers built into the Windows ME, 2000 and XP operating systems in order to communicate with the PC. Once you plug in and power up the camera, the operating system will automatically recognize the device and install the necessary drivers. The camera will be assigned a drive letter and listed as an external mass storage device (disk drive).

At this point, you can read files and images from the camera. However, ***do not attempt to write information back to the camera*** (e.g. by saving or copying files). While this won't do any damage to the camera, it may confuse the operating system and eventually require a camera reset (simply unplug the USB cable and reconnect it) in order to resolve any conflicts.

3. Software Installation

Your Shad-o-Snap camera ships with a CD containing a PDF version of this manual, installation files for the Camera Console and ShadoCam applications, a factory-calibrated pixel map for your camera, data sheets, and other useful information.

3.1 Installing CameraConsole

The CameraConsole application is an easy-to-use interface to the Shad-o-Snap camera. With CameraConsole you can control the camera settings, acquire images, and transfer image files to the PC for viewing and archiving. CameraConsole is installed automatically as part of the ShadoCam installation (see next section).

3.2 Installing ShadoCam

The ShadoCam application is used to acquire and view 16-bit "raw" image files produced by the Shad-o-Snap camera. To install ShadoCam, place the CD in your PC's CD drive and follow the prompts from the installation menu.

After the installation has completed, start up ShadoCam and select the correct camera preference for your Shad-o-Snap camera. For instructions on preference settings and other program functions please refer to the extensive ShadoCam help file that is installed with the program. You can also check our website (www.rad-icon.com) for the latest updates.

3.3 Preparing the Pixel Map

Your Shad-o-Snap camera comes with a factory-calibrated pixel map that works with ShadoCam to automatically perform pixel corrections on any acquired images. This pixel map needs to be copied into ShadoCam's default data directory where the program can access it (e.g. "C:\Program Files\ShadoCam"). You can edit the pixel map in ShadoCam to suit your specific requirements. Make sure to create a back-up copy of the factory-supplied pixel map in a safe location on your hard drive so you can revert to it if necessary. For more information on pixel maps and image corrections please refer to the help file.

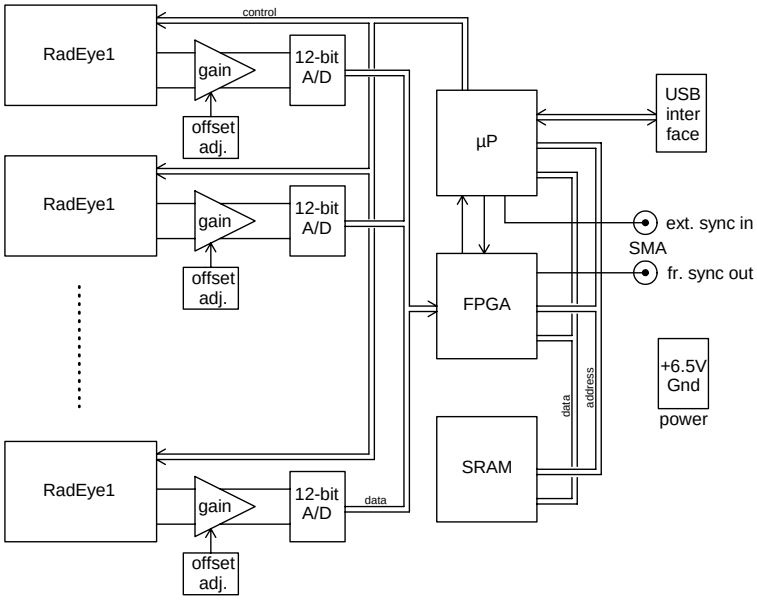
4. Camera Operation and Timing

The Shad-o-Snap camera hardware consists of an array of RadEye1 image sensors, an analog data acquisition section and a digital camera controller section. A block diagram of the camera electronics is shown on the next page. The analog output from each sensor is amplified, offset adjusted and digitized to 12 bits. The digitized data streams are then multiplexed by the sensor controller FPGA and written to the camera's SRAM. An on-board microprocessor handles the USB interface, generates the sensor control signals and performs any image processing functions such as offset correction.

In the default ***Timing Mode "0"*** all camera timing signals are generated internally. The detector integration time (period from one frame readout cycle to the next) can be set via the USB interface. The minimum integration time is 540 ms, the length of one readout cycle. However, it is possible to set a shorter integration time in which case only a partial frame is scanned.

Depending on the camera model, the readout cycle either starts at the center of the image and proceeds to scan row sequentially towards the top and bottom (see figure next page), or it scans just a subset of that pattern. The image is scanned in several parallel sections and reassembled inside the camera memory.

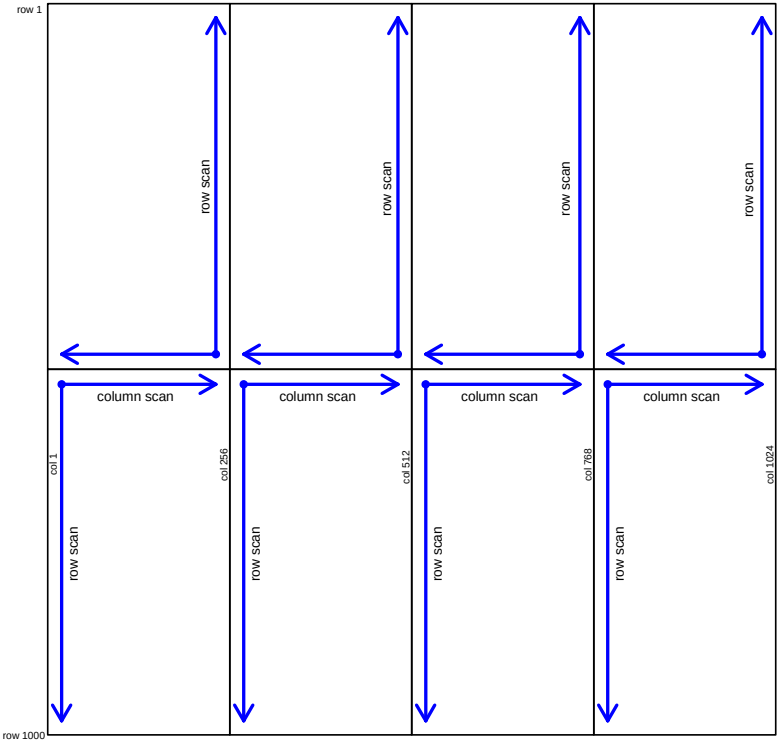
Shad-o-Snap Electronics Block Diagram



The CMOS photodiode array inside the Shad-o-Snap camera is always integrating signal and therefore needs to be reset periodically. The reset operation is performed automatically during the readout cycle. As each row is scanned during the readout cycle, the photodiodes in that row are reset. A periodic readout is required in order to prevent the detector from saturating. This readout signal is automatically generated by the microprocessor, and any signal (image) stored in the detector is lost unless the camera receives a USB command to save the image data into its internal memory. In this case the next available image will be transferred and can then be accessed through the USB interface (see Appendix D for more information about the image acquisition process).

The maximum integration time that can be set via the USB interface in ***Timing Mode "0"*** is 33.5 seconds. It is possible to use longer integration times by controlling the camera

Camera image scan (shown for Shad-o-Snap 1K)

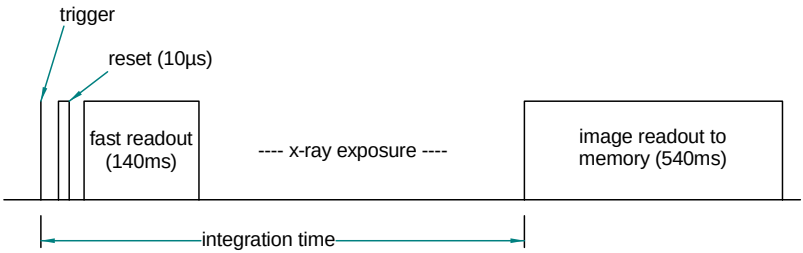


integration time through the "Ext. Sync In" SMA connector on the front panel. This mode is enabled by selecting ***Timing Mode "1"*** on the CameraConsole interface. In this case, the rising edge of a TTL or 0-5 V input signal will trigger a frame readout cycle. The time delay between successive edges determines the integration time.

A third camera timing mode uses an electronic shutter to work with timed x-ray exposures. In this case either a software trigger (via the USB interface) or a hardware trigger (a rising edge on the "Ext. Sync In" input) starts a programmed timing sequence which first resets the photodiode array, then waits and integrates for a preselected period of time, and then reads out the image.

The following figure illustrates this process. In ***Timing Mode "2"*** the reset is performed by a 10µs long global reset pulse followed by a "fast readout" scan which takes 140ms to clear the array. This method has the advantage of producing a more uniform image. The actual signal integration period then follows, determined by the integration time setting selected for the camera. At the end of the integration period, a normal readout scan takes place and the image is transferred into memory, from where it can be accessed via the USB interface.

Timing Mode "3" follows the same exact sequence except that the "fast readout" scan is skipped. This means that the camera starts integrating x-rays within a few microseconds of the trigger event. However, the short reset pulse produces some non-uniformities and small signal fluctuations in the image. It is recommended to use ***Timing Mode "2"*** whenever possible.



Timing Mode "2" (not to scale)

The camera operation can be checked by monitoring the signal on the "Frame Sync Out" SMA connector. The signal on this connector is at a "high" level whenever the sensor is reading out its image. The "Frame Sync Out" signal is low during the period between readout cycles when the sensor is integrating an image. A small LED in series with a 100-200 Ohm resistor may be connected to this port as a simple monitoring device.

Appendix A: Camera Specifications

(Shad-o-Snap 1K; see data sheet for other models)

Sensor size (cols x rows)	1024 x 1000 pixels
Active area (width x height)	98.6 x 96.1 mm
Pixel spacing (pitch)	0.096 mm
Avg. dark current (23°C) [1]	8 ADU/sec [2]
Read noise (rms)	< 1 ADU
Dynamic range	4000:1
Digitization	12 bits (4096 ADU)
Conversion gain	500 electrons/ADU
Readout period [3]	540 ms
Supply voltage	6-8 V (6.5 V typ.)
Maximum supply current	750 mA
Typical power dissipation	< 5 W
Data interface	USB 1.1
Image transfer time to PC	
Thumbnail (TIFF)	~0.5 sec
Full image (RAW)	3-4 sec
SMA connector interface	TTL
Operating temperature	0 to 50 °C
Storage temperature	-25 to +85 °C
Humidity (non-condensing)	10 to 80 % R.H.
Weight	3.5 kg

[1] dark current doubles approximately every 8 °C
[2] ADU = Analog-Digital Unit ≡ 1 LSB (Least Significant Bit)
[3] time required to transfer image from sensor to camera memory

Appendix B: Electromagnetic Compliance

This equipment complies with the requirements of the 89/336/EEC Electromagnetic Compatibility Directive as well as with the limits for a Class A digital device pursuant to Part 15 of the FCC Rules. The equipment has been tested to the following specifications:

- EN 55022: 1998 (Class A)
- EN 61000-3-2: 2001
- EN 61000-3-3: 1995 plus A1:2001
- EN 55024: 1998 plus A1:2001

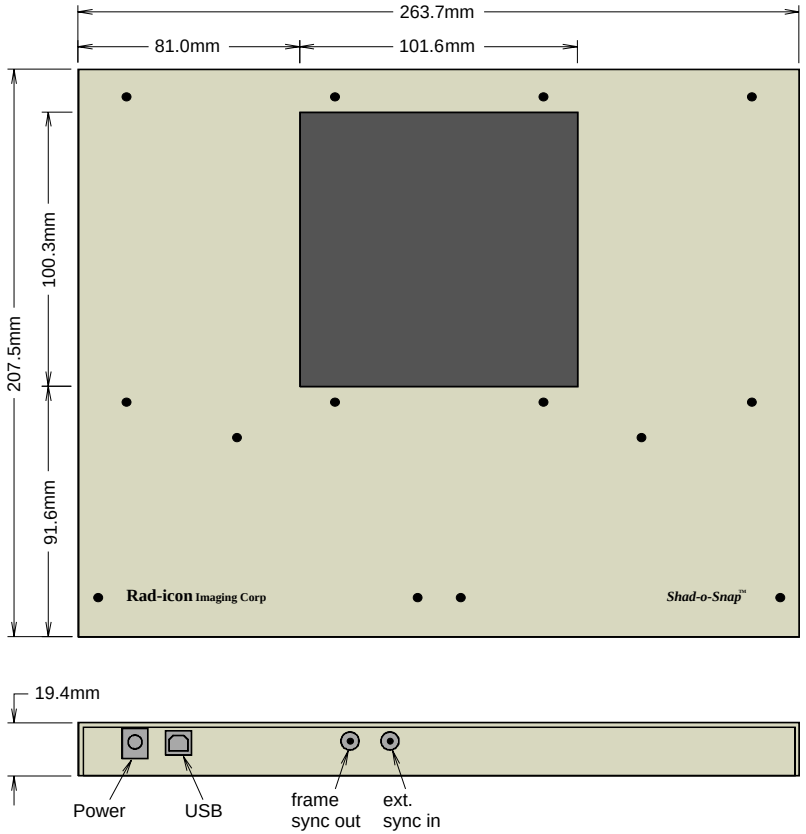
The test limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference, in which case the user will be required to correct the interference at his own expense.

Note: The EMC performance of this product was verified under test conditions that included the use of shielded cables and connectors. To maximize compliance in your application follow these specific guidelines:

- Keep control and data cables as short as possible.
- Control and data cables must have 95% coverage shields that include braided wire. Metallic foil shields are insufficient without braided wire.
- Ensure that all cable shields have 360° electrical connection to the connector backshell.

Appendix C: Physical Dimensions

Shad-o-Snap 1K & 4K; see data sheet for other models



Power Connector:

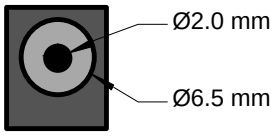
DC power jack, 2.0 mm center pin diameter. Fits standard female power plug with 2.1 mm inside diameter and 5.5 mm outside diameter.

center pin:

6.5 VDC

outside:

ground

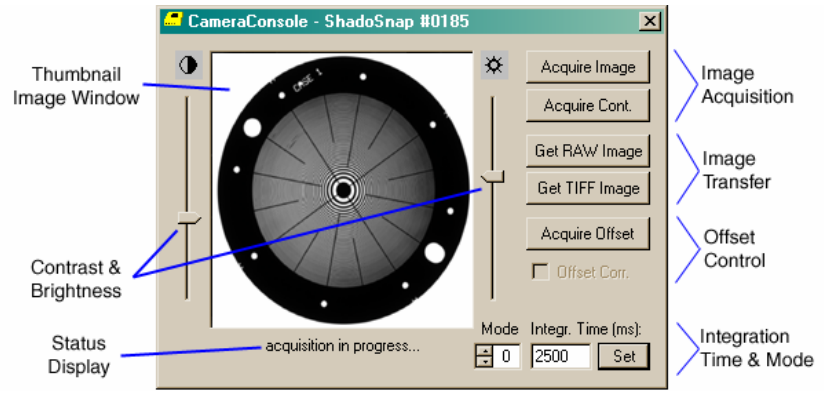


Appendix D: CameraConsole Interface

The CameraConsole interface provides a quick and easy way to control the settings of your Shad-o-Snap camera and to acquire and retrieve images. The CameraConsole front panel consists of a thumbnail display window with contrast and brightness controls, a status display, and a set of buttons and controls for adjusting the camera settings. The status display is normally blank unless the camera is in the process of acquiring or transferring an image. The serial number of the Shad-o-Snap camera connected to your computer is displayed in the title bar.

The thumbnail image window displays a low-resolution (128x124 pixels) preview of the image currently stored in the camera. The display is blank if there is no valid image to display (e.g. right after the power was turned on). You can use the two slide controls to the left and right of the image window to adjust the contrast and brightness of the image.

The bit depth of the thumbnail and TIFF images in the camera is only eight bits. CameraConsole automatically selects which eight bits to read based on the contrast and brightness settings. This means some image details can get clipped. To view the full twelve bits you need to transfer the RAW image to ShadoCam.



Appendix D: CameraConsole Interface

The two image acquisition buttons are used to acquire new images and update the thumbnail display. Click on the "Acquire Image" button to acquire a single image. This tells the camera to take the next available image from the sensor and store it in its memory. The "Acquire Cont." button can be used to provide a live video display.

After the image has been acquired, it still resides in the camera memory. The image transfer buttons are used to move the image over the USB link to the PC. Once transferred, CameraConsole opens the image with the default program for viewing either the "RAW" image type (usually ShadoCam) or the "TIF" image type (e.g. PhotoShop).

The offset controls access the Shad-o-Snap camera's offset correction functions. You have to first acquire an offset image in order to enable the offset correction checkbox. Note that the offset image that is stored in the camera only holds 8-bit pixel values. Any pixel values greater than 255 will be clipped. The camera automatically adds a constant offset of 10 ADU to any offset-corrected image in order to prevent negative pixel values. Please read the "Easy Guide" or the ShadoCam help file for more information regarding image corrections.

Finally, the integration time and timing mode controls are used to adjust the camera's internal timing. The different timing modes are described in section 4 of this manual. The integration time setting applies to modes 0, 2 and 3 only. In mode 0, a time setting of less than 540ms will result in a partial frame readout. Only the section of the image where the scan starts will be updated. In mode 2 the minimum integration time is 150ms.

Appendix E: Technical Support

For technical assistance with the CameraConsole software, the ShadoCam software or your Shad-o-Snap camera please contact our customer service department (8 am to 6 pm PST) at 408-486-0886, or send us an E-mail at "support@rad-icon.com". Please be prepared to give a detailed description of your problem. Some of the information we may need includes:

- The version of ShadoCam you have installed on your system.
- The name and version of your operating system and your BIOS.
- The type of hardware (CPU, PCI chipset, frame grabber) you are using.
- The model number and serial number of the Shad-o-Snap camera you are using.

For the latest information and updates please visit our web site at "http://www.rad-icon.com".

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