Ladybug3™

Technical Reference Manual

Version 1.8
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Point Grey Research® Inc.
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FCC Compliance Information

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These 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.

You are cautioned that any changes or modifications not expressly approved in this manual could void your authority to operate this equipment.

Hardware Warranty

Point Grey Research®, Inc. (Point Grey) warrants to the Original Purchaser that the Camera Module provided with this package is guaranteed to be free from material and manufacturing defects for a period of one (1) year. Should a unit fail during this period, Point Grey will, at its option, repair or replace the damaged unit. Repaired or replaced units will be covered for the remainder of the original equipment warranty period. This warranty does not apply to units that, after being examined by Point Grey, have been found to have failed due to customer abuse, mishandling, alteration, improper installation or negligence. If the original camera module is housed within a case, removing the case for any purpose voids this warranty.

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WEEE

The symbol indicates that this product may not be treated as household waste. Please ensure this product is properly disposed as inappropriate waste handling of this product may cause potential hazards to the environment and human health. For more detailed information about recycling of this product, please contact Point Grey Research.

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1. Introduction

1.1 Ladybug3 Overview

The *Ladybug3* spherical digital camera offers high megapixel resolution and wide coverage at a high-speed interface. The camera's six 1600 x 1200 Sony CCD sensors cover more than 80 percent of a full sphere, and are pre-calibrated to enable high quality spherical image stitching. With an ultra fast IEEE-1394b 800Mb/s digital interface, the *Ladybug3* is particularly effective in demanding spherical video applications requiring high-performance synchronization of images.

Refer to Knowledge Base Article 206 for a complete overview of the features and benefits of the IEEE-1394b standard.

*All model-specific information presented in this manual reflects functionality available in firmware version **1.3.2-04**.*

To check the camera firmware version, consult our knowledge base: www.ptgrey.com/support/kb/index.asp?a=4&q=94.

Feature	Description
Field of View	Six (6) 3.3 mm focal length microlenses covering >80 of the full sphere
IEEE-1394b Bandwidth	800Mb/s interface allows full color RGB output at high data rates
Programmable Exposure	User-programmable shutter, gain, and black clamp settings via software
Trigger at Full Frame Rate	Overlapped trigger input, image acquisition and transfer
Frame Rate Control	Fine-tune frame rates
Serial Port	Provides serial communication via GPIO TTL digital logic levels
Memory Channels	Non-volatile storage of camera default power-up settings
Camera Upgrades	Firmware upgradeable in field via IEEE-1394 interface.
Waterproof Design	IP Code 67 compliant
Jack Screw Connector	1394b cable jack screws provide secure connection

1.2 Using This Manual

This manual attempts to provide the user with a detailed specification of the *Ladybug3* camera system. The reader should be aware that the camera system is a complex and dynamic system – if any errors or omissions are found during experimentation, please contact us.

This document is subject to change without notice.

Many of the operational descriptions included in this manual are intended as general overviews, and may not present the detailed information required for developing specific applications. For additional details and operational descriptions, refer to the following resources that can be downloaded from our website at www.ptgrey.com/support/downloads/:

- *Ladybug SDK Help*, available through *Point Grey Research* on the Start Menu, or at www.ptgrey.com/support/downloads/.
- The Point Grey knowledge base, available at www.ptgrey.com/support/kb/index.asp.
- *Point Grey Digital Camera Register Reference*, available at www.ptgrey.com/support/downloads/.

1.3 Camera Specifications

General Camera Specifications	
Camera Model	LD3-20S4C
Overview	Single unit, high-resolution IEEE-1394b spherical digital video camera
Imaging Sensor Type	Six (6) Sony progressive scan color CCDs (five in horizontal ring, one on top)
Image Sensor Model	Sony 2.0 MP 1/1.8" ICX274
Maximum Resolution	1616(H) x 1232(V) (each sensor)
Pixel Size	4.4 µm(H) x 4.4 µm(V)
A/D Converter	Analog Devices 12-bit ADC
Effective Imager Size	6.26 mm(H) x 5.01 mm(V)
Video Data Output	8-bit raw Bayer (color) digital data
Signal To Noise Ratio	62 dB at 0 dB gain
Digital Interfaces	9-pin 1394b (FireWire) 800 Mb/s for camera control, video data transmission and power.
Optical Specifications	
Lenses	Six (6) 3.3 mm focal length microlenses
Field of view	>80% of full sphere
Spherical Distance	Calibrated at 20 m
Focus Distance	Approx. 200 cm. Objects have an acceptable sharpness from approx. 60 cm to infinity
Parallax	48 mm offset between optical centers of side cameras 72 mm offset between optical centers of top camera and side cameras
Operational Specifications	
Maximum Frame Rate	16 FPS JPEG compressed 6.5 FPS uncompressed
General Purpose I/O ports	8-pin GPIO connector for trigger strobe, serial port or external power
Gain	Automatic/Manual/One-Push Gain modes, programmable via software, -2.25 dB to 24 dB in 0.04 dB increments
Gamma	0.5 – 4.0
Shutter	Automatic/Manual/One-Push modes, programmable via software, 0.01 ms to 4.2 s (extended shutter mode)
White Balance	Manual
JPEG Compression	Auto or manual quality control; Auto buffer usage control
Synchronization	Via software trigger (if on same bus) or free-running
Memory Storage	3 memory channels for custom camera settings
Electrical and Mechanical Specifications	
Power Requirements	8-30 V via the IEEE 1394b cable or 8-pin GPIO connector
Power Consumption	7.2W (max) at 12V
Camera Housing	Machined aluminum housing, anodized red, water-resistant
Dimensions (W x H)	134mm x 141mm

Mass	Camera head: 2.416 Kg Mounting support and base: tbd
Camera Specification	IIDC 1394-based Digital Camera Specification v1.31
Emissions Compliance	Complies with CE rules and Part 15 Class A of FCC Rules.
Operating Temperature	Commercial grade electronics rated from 0° - 45°C
Storage Temperature	-30° - 60°C
Operating Relative Humidity	20 to 80% (no condensation)
Storage Relative Humidity	20 to 95% (no condensation)
Current Firmware Version	1.2.2-00
Warranty	1 year

1.3.1 Spectral Response

***Color cameras** are equipped with an optical filter that prevents infrared light from reaching the image sensor. This filter is discussed in the section on **Infrared Cut-Off Filters**.*

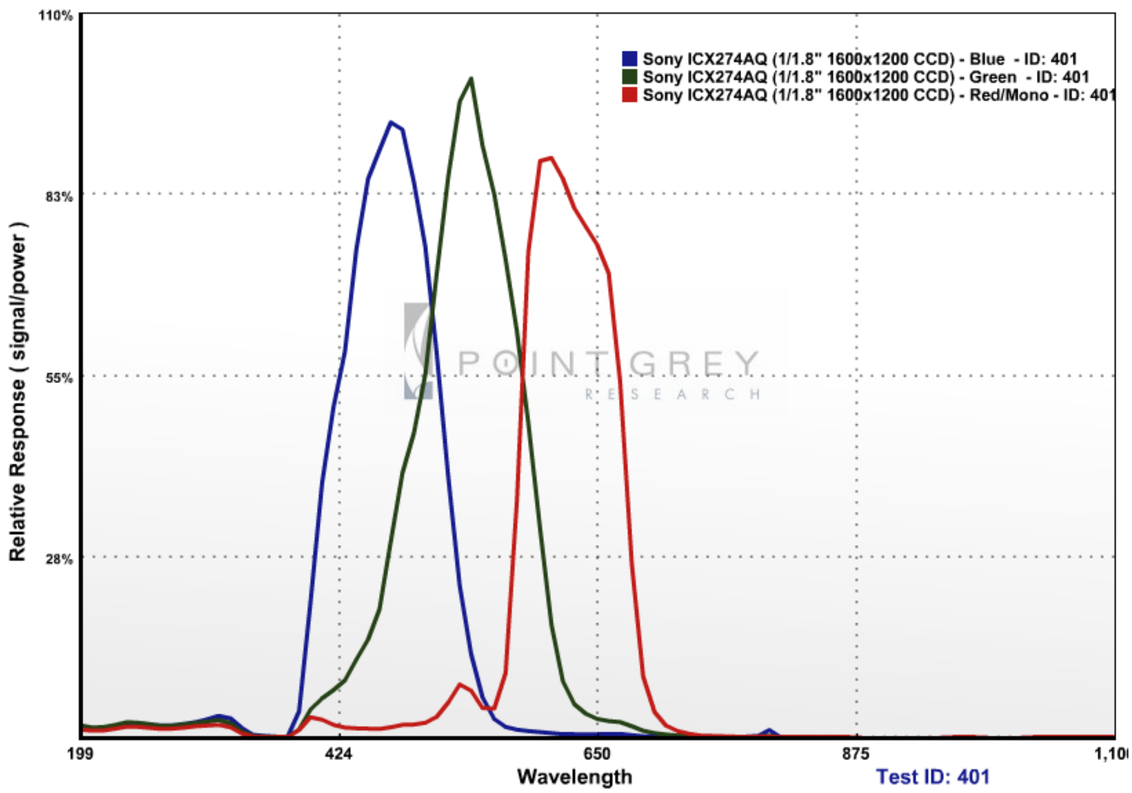

Figure 1: Ladybug3 Spectral Response Curve

1.3.2 Common CCD Artifacts

The following section describes issues typical of CCD sensors and possible solutions.

- **Dead / Hot Pixels**
  It is possible for one or more pixels in the CCD sensor array to stop responding. This will result in a situation where the pixel will always appear black (dead), or white (hot/stuck). This is generally not an issue except in very rare cases.

- **Bright Pixels**
  Cosmic rays have the ability to cause images to have artifacts which look like hot pixels which are randomly distributed throughout the image. This is most apparent when the camera is running at a high temperature or the gain is set to a high amount. It is impossible to prevent cosmic rays from reaching the CCD.

- **Vertical Smear**
  When a strong light source is shot on the camera, there may be a vertical smear above and below the position of the actual light source. This is a byproduct of the interline transfer system used to extract data from the CCD.

1.3.3 On-Camera Data Flow

The diagram below depicts the flow of image data on the *Ladybug3* from capture, through manipulation, to output. The table that follows describes the steps in more detail.

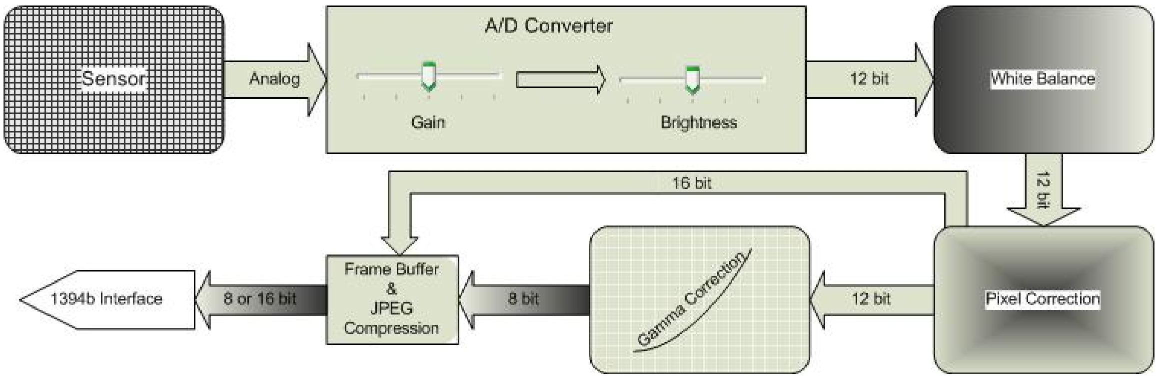

Figure 2: Ladybug3 data flow diagram

Image Flow Step	Description
Sensor	Each of the six Sony® ICX274 CCD sensors produces voltage signals in each pixel from the optical input.
Analog to Digital (A/D) Converter	Each sensor's A/D Converter transforms pixel voltage into a 12-bit value, adjusting for gain and brightness in the process. The *Ladybug3* supports automatic, manual and one-push gain control, and manual brightness control. Gain and brightness cannot be turned off.
White Balance	Color intensities can be adjusted manually to achieve more correct balance. White Balance is ON by default. If not ON, no white balance correction occurs.
Defect Correction	The camera firmware corrects any blemish pixels identified during manufacturing quality assurance by applying the average value of neighboring pixels.
Gamma/Lookup Table	Gamma can be manually adjusted. When performing gamma correction, the camera firmware uses a lookup table that accepts 11 bits of input per pixel, and outputs an 8-bit value. By default gamma adjustment is OFF, and no correction occurs. Gamma correction is not available if the camera is in a 16-bit image format.
Frame Buffer & JPEG Compression	Image data accumulates in a 128-MB on-camera frame buffer, primarily to perform JPEG compression. Following compression, image data is output in either 8- or 16-bit format via the IEEE-1394b interface.

1.3.4 Imaging Process Overview

The following diagram shows how image data that is captured by a *Ladybug3* camera in JPEG compressed format can be processed for display on a PC using the Ladybug API. The table that follows describes the steps in more detail. For more information about the on-camera flow of image data, refer to Section 1.3.3.

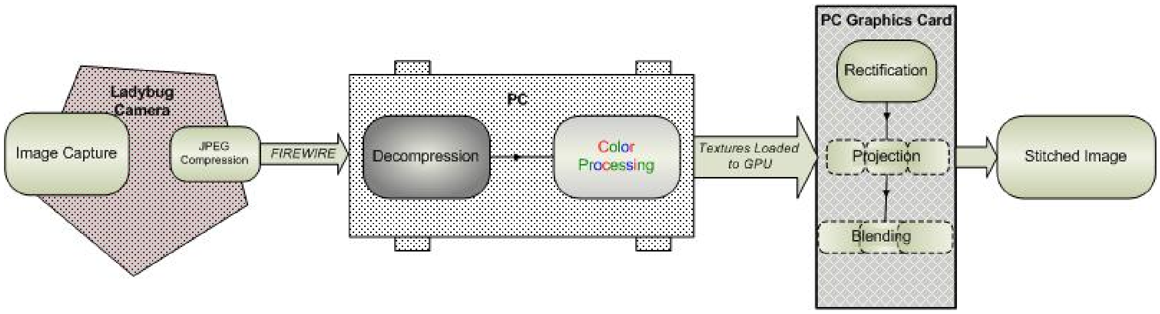

Figure 3: Ladybug3 Imaging Process

Imaging Step	Description
Image Capture	Separate images are captured from each of the camera's six sensors and undergo image processing, including analog-to –digital conversion to raw (Bayer-tiled) format, gain, auto-exposure and white balance.
JPEG Compression	If the camera is programmed accordingly, each image is converted into JPEG compressed format. For more information, see Section 4.3. JPEG compressed mode allows for images to be transmitted to the PC at a faster frame rate. Following compression, images are transmitted to the PC via the FireWire cable.
Decompression	Images are decoded back into raw image format for further processing.
Color Processing	The raw Bayer-tiled images are interpolated to create a full RGB images. For more information, see Section 4.5.1. Following color processing, images are loaded onto the graphics card of the PC for rectification, projection and blending.
Rectification	Rectification corrects the barrel distortion caused by the *Ladybug3* lenses.
Projection	Image textures are mapped to a single 2- or 3-dimensional coordinate system, depending on the projection that is specified.
Blending	Pixel values in each image that overlap with the fields of adjacent images are adjusted to minimize the effect of pronounced borders. The result is a single, stitched image.

Table 1: Ladybug3 Imaging Process Steps

After capturing images in JPEG compressed format, you can use the Ladybug API to perform the remaining tasks on the PC. For more information, refer to the *LadybugPanoramic* (Windows application) and *LadybugPanoStitchExample* (console application) examples in the Ladybug SDK Help.

The stitching process assumes that all points in the field of view are 20 meters from the camera. This measure produces optimal results for most types of outdoor use. To have your *Ladybug3* camera calibrated for a different spherical distance, contact support@ptgrey.com.

Related Knowledge Base Articles

ID	Title	URL
250	Overview of the Ladybug image stitching process	http://www.ptgrey.com/support/kb/index.asp?a=4&q=250
222	How does changing the compression level affect the quality of Ladybug2 images?	http://www.ptgrey.com/support/kb/index.asp?a=4&q=222
288	Ladybug2's JPEG image quality and buffer usage settings	http://www.ptgrey.com/support/kb/index.asp?a=4&q=288
227	How does the Ladybug2 rectification process work?	http://www.ptgrey.com/support/kb/index.asp?a=4&q=227
251	Improved calibration process for Ladybug cameras	http://www.ptgrey.com/support/kb/index.asp?a=4&q=251

1.4 System Requirements

Recommended Requirements

The following system configuration will allow for display of stitched panoramic images and for displaying and saving stream data at maximum bandwidth capacity.

- Intel Core2 Duo or Quad processor or compatible processor
- 2GB of RAM
- NVIDIA video card with 512 MB RAM
- IEEE-1394b PCI Express interface card
- Striped disk RAID array to store stream data at more than 80 MB/sec.
- Windows XP Service Pack 1 or Windows Vista
- Point Grey FirePRO driver
- Microsoft Visual Studio 2005 (to compile and run example code)

1.4.1 Laptop / Notebook Considerations

Ladybug3 users should consider power and bandwidth issues when running the camera unit on a laptop or notebook computer. For more information, refer to the following knowledge base article:

KB Article 246: http://www.ptgrey.com/support/kb/index.asp?a=4&q=246

Some 1394 PCMCIA cards for laptop / notebook computers require a 4-pin cable. A 4-pin cable does not provide power and will therefore not work with Point Grey cameras, which require a 6-pin connector (the additional two pins provide power). For suggestions on how to provide power in these circumstances, consult the following knowledge base article:

KB Article 93: www.ptgrey.com/support/kb/index.asp?a=4&q=93

1.4.2 Macintosh and Linux OS Support

Users wishing to operate a *Ladybug3* on the Macintosh OS/X or Linux operating systems can view and save raw image data in uncompressed format only. There are no Macintosh or Linux-compatible device drivers that allow for full image processing on the PC. Decompression from JPEG compressed format, color processing, rectification, blending and stitching are not supported.

Related Knowledge Base Articles

ID	Title	URL
173	Using PGR Imaging Products under Macintosh OS X	http://www.ptgrey.com/support/kb/index.asp?a=4&q=173
17	Using PGR Imaging Products under Linux	http://www.ptgrey.com/support/kb/index.asp?a=4&q=17

1.5 Controlling the Camera

The *Ladybug3* can be controlled using the LadybugCap and LadybugCapPro programs:

To run these programs from the Start menu, select Program Files > Point Grey Research > PGR Ladybug > LadybugCap.exe or LadybugCapPro.exe. For more information, refer to the Ladybug SDK Help.

1.5.1 LadybugCap Program

The LadybugCap program can be used to test many of the capabilities of your *Ladybug3* camera. It allows you to do the following:

- View a live video stream from the camera.
- Display fully stitched panoramic and spherical images.
- Save individual panoramic images or stream files.
- Adjust frame rates, properties and settings of the camera
- Access camera registers.

The full LadybugCap C/C++ source code is included with the Ladybug3 SDK. To access the LadybugCap workspace from the Start menu, select Program Files → Point Grey Research Inc. → PGR Ladybug → Examples → LadybugCap project. Microsoft Visual Studio is required to open and compile the project.

1.5.2 LadybugCapPro Program

The LadybugCapPro application contains all of the functionality of LadybugCap. Additionally, it can be used in conjunction with a GPS device, which can then be recorded into a stream. The GPS data can then be converted into Google Maps or Google Earth format.

1.5.3 Custom Applications Built with the Ladybug API

PGR Ladybug includes a full Application Programming Interface that allows customers to create custom applications to control Point Grey spherical vision products. The SDK provides a number of sample programs and source code that is meant to help the advanced programmer get started using the Ladybug API. Examples range from simple console programs that demonstrate the basic functionality of the API, such as *LadybugSmpleGrab*, to more complex examples such as *ladybugAdvancedRenderEx*.

1.6 Camera Control Command Registers

For a complete description of the Camera Control Command Registers implemented on the camera, please refer to the *Point Grey Research Digital Camera Register Reference*, downloadable from www.ptgrey.com/support/downloads/.

1.7 Handling Precautions and Camera Care

> *Do not open the camera housing. Doing so voids the* Hardware Warranty *described at the beginning of this reference manual.*

Your Point Grey digital camera module is a precisely manufactured device and should be handled with care. Here are some tips on how to care for the device.

- Avoid electrostatic charging. Please consult the following knowledge base article for more details: www.ptgrey.com/support/kb/index.asp?a=4&q=42.
- When handling the camera unit, avoid touching the lenses. Fingerprints will affect the quality of the image produced by the device.
- To clean the lenses, use a standard camera lens cleaning kit or a clean dry cotton cloth. Do not apply excessive force.
- Avoid excessive shaking, dropping or any kind of mishandling of the device.

1.8 Camera Accessories

Accessories such as tripod mounts and lens holders are available from PGR – contact our Sales team at sales@ptgrey.com for additional information. Links to FireWire/IEEE-1394 and digital camera accessories can be found in the following knowledge base article:

KB Article 131: www.ptgrey.com/support/kb/index.asp?a=4&q=131.

2. Camera Physical Properties

2.1 Camera Description and Dimensions

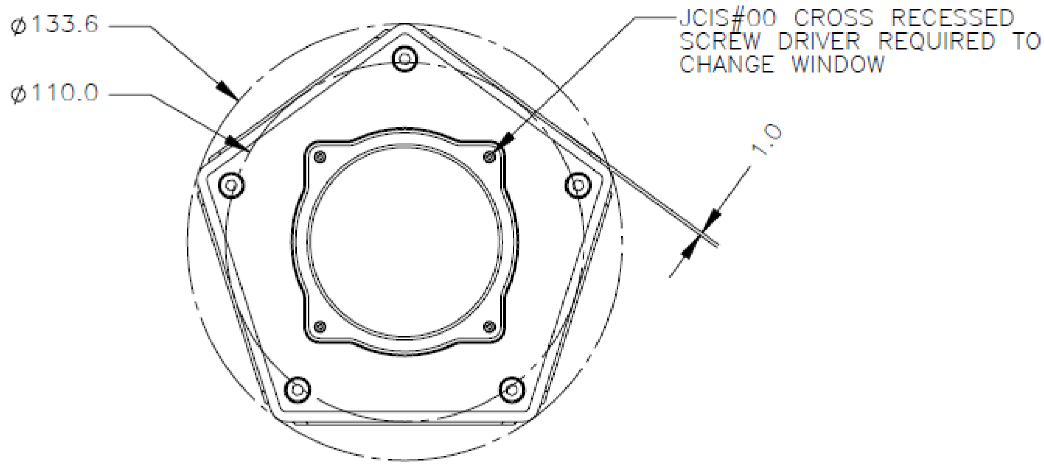

Figure 4: Camera dimensional drawing, top view (measurements in mm)

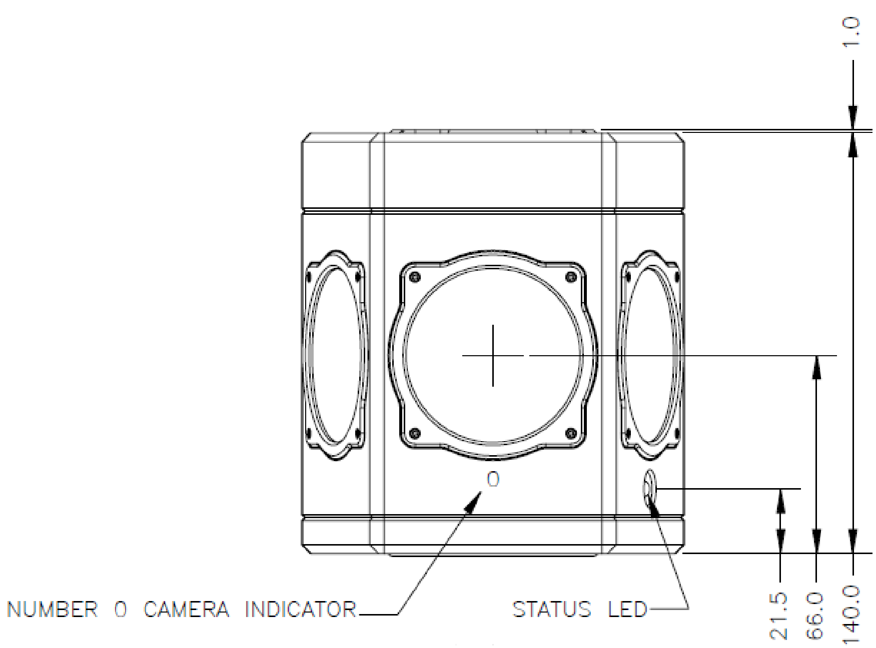

Figure 5: Camera dimensional drawing, side view (measurements in mm)

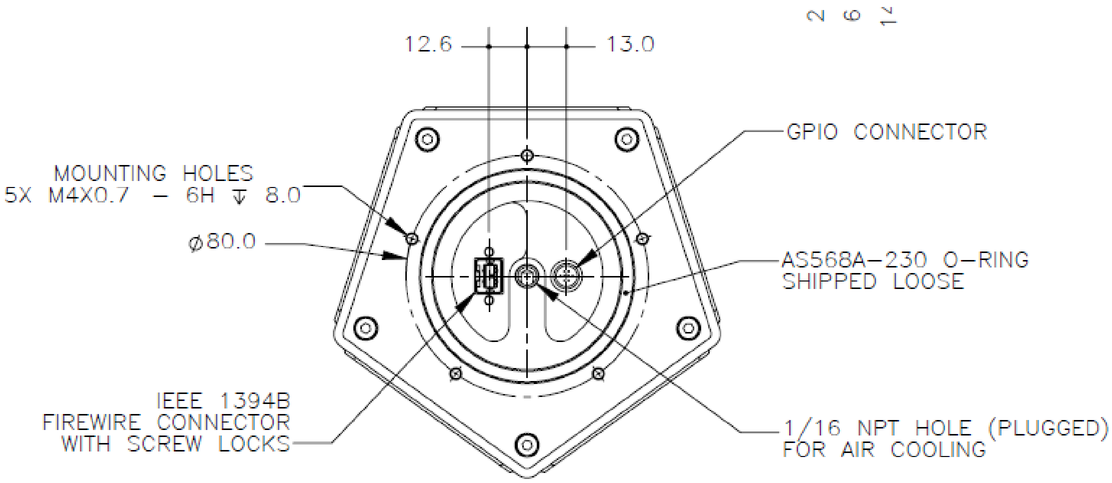

Figure 6: Camera dimensional drawing, bottom view (measurements in mm)

2.2 Desktop Mount Description and Dimensions

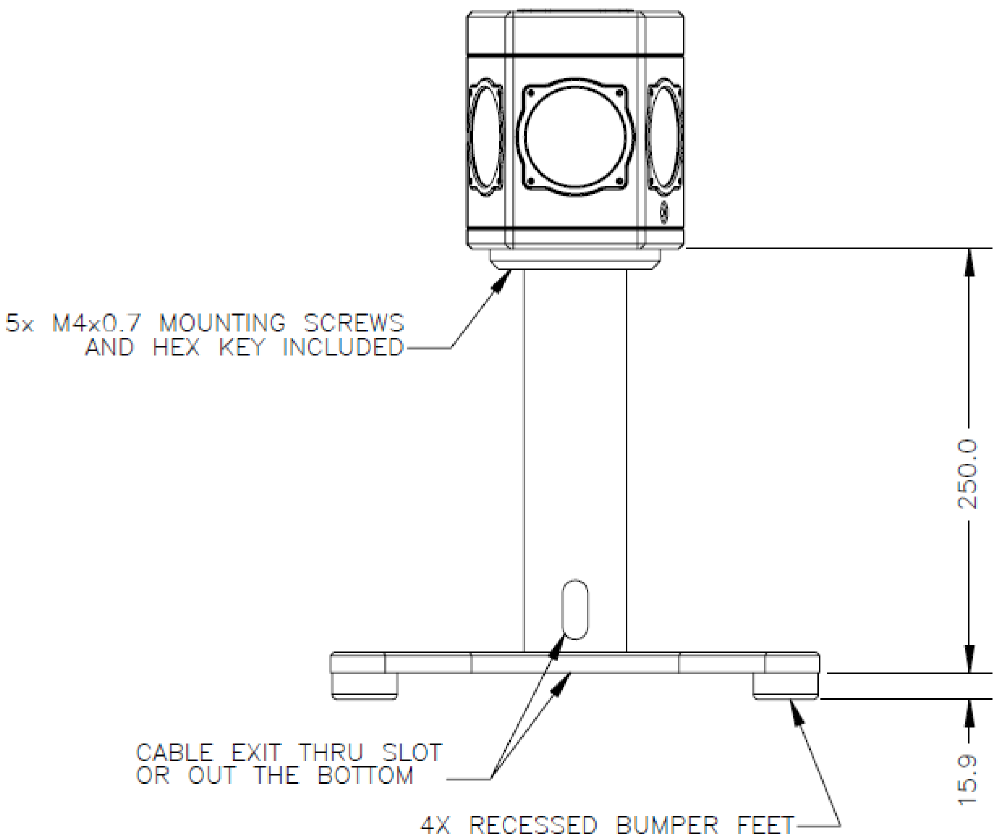

Figure 7: Mounting support dimensional drawing, side view (measurements in mm)

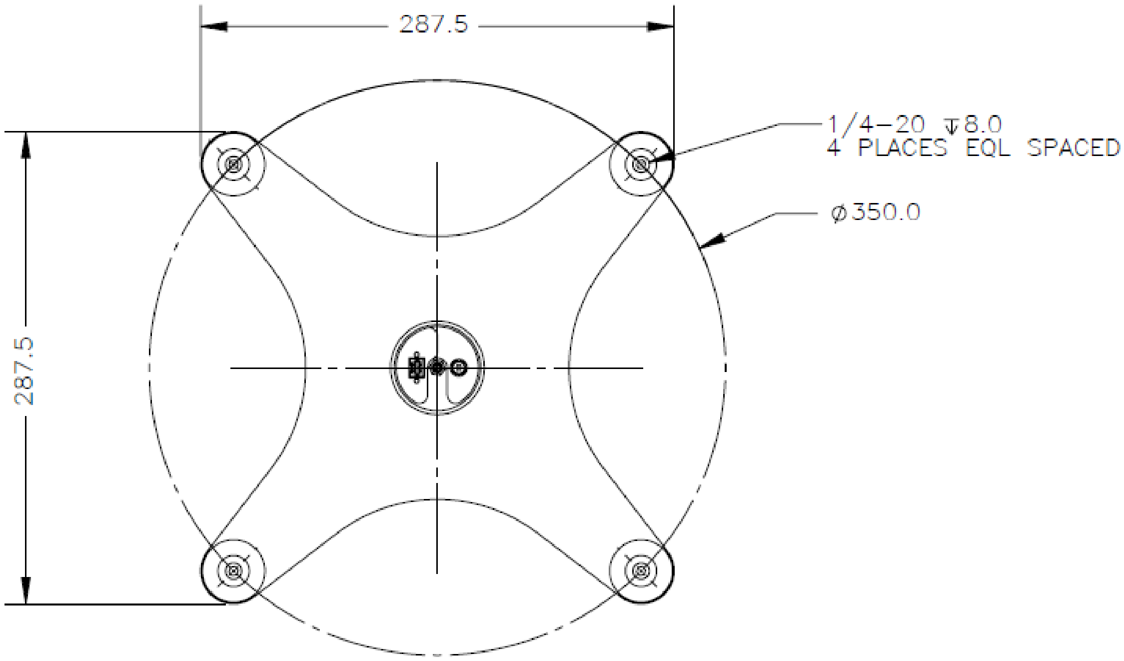

Figure 8: Mounting support dimensional drawing, bottom view (measurements in mm)

2.3 Tripod Adapter Description and Dimensions

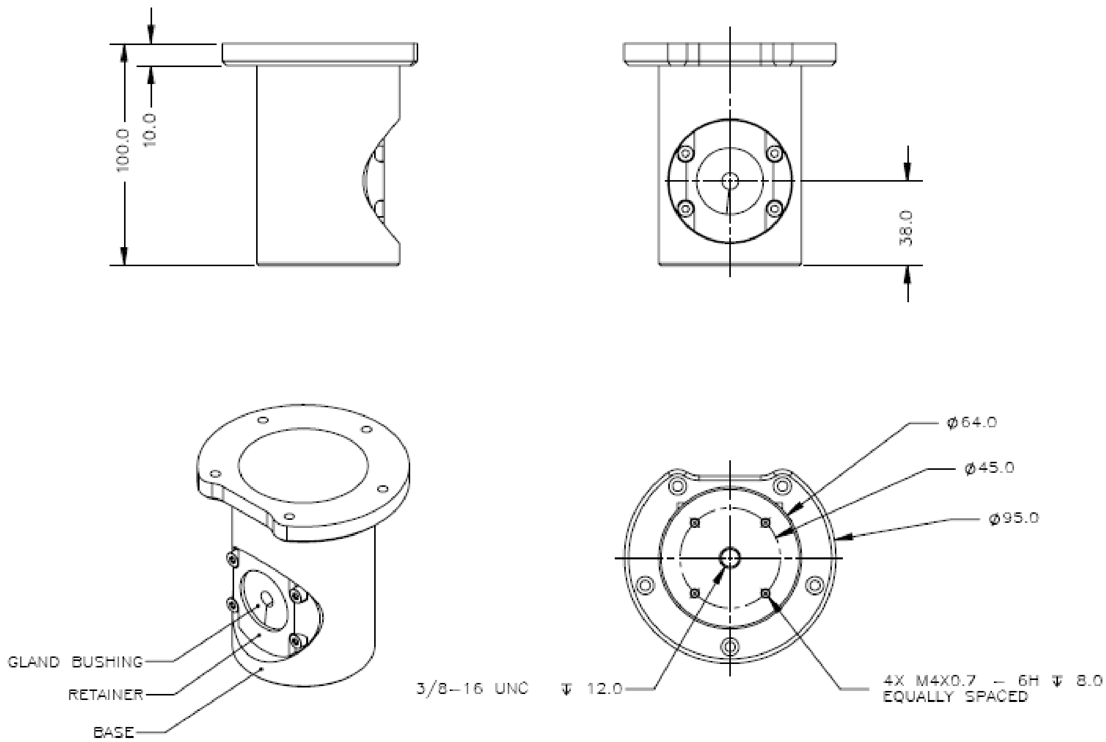

Figure 9: Ladybug3 Tripod Adapter

2.4 Protecting the Camera from External Elements

2.4.1 Water and Dust Protection

To protect against dust and water, the *Ladybug3* camera housing includes a sealed layer of glass, with anti-reflective coating on both sides, over each of the six lenses.

Because the camera bottom contains outside interfaces, the camera should be operated in rainy weather only when connected to the desktop mount or the tripod adapter. The Ladybug3 should not be submerged under water in any circumstances.

2.4.2 Temperature Control

The *Ladybug3* is equipped with an on-board temperature sensor. It allows you to obtain the ambient temperature within the camera housing. This feature can be accessed using the TEMPERATURE register 0x82C.

2.5 Mounting

2.5.1 Using the Case

The case is equipped with five M4 X 0.7 mounting holes on the bottom of the case that can be used to attach the camera directly to the *Ladybug3* desktop mount, tripod adapter, or a custom mount. To create a seal between the camera and the mount, make sure the AS568A-230 O-ring is properly fitted. For more information about the location of the O-ring, refer to Figure 6 in Section 2.1.

2.5.2 Using the Desktop Mount

The *Ladybug3* desktop mount comes with the Development Kit, or can be purchased separately by contacting sales@ptgrey.com.

For information about how to use the desktop mount when capturing images in a mobile setting, refer to Knowledge Base Article 302.

> *To create a seal between the camera and the mount, make sure the* AS568A-230 *O-ring is properly fitted. For more information about the location of the O-ring, refer to* Figure 6 *in* Section 2.1*.*

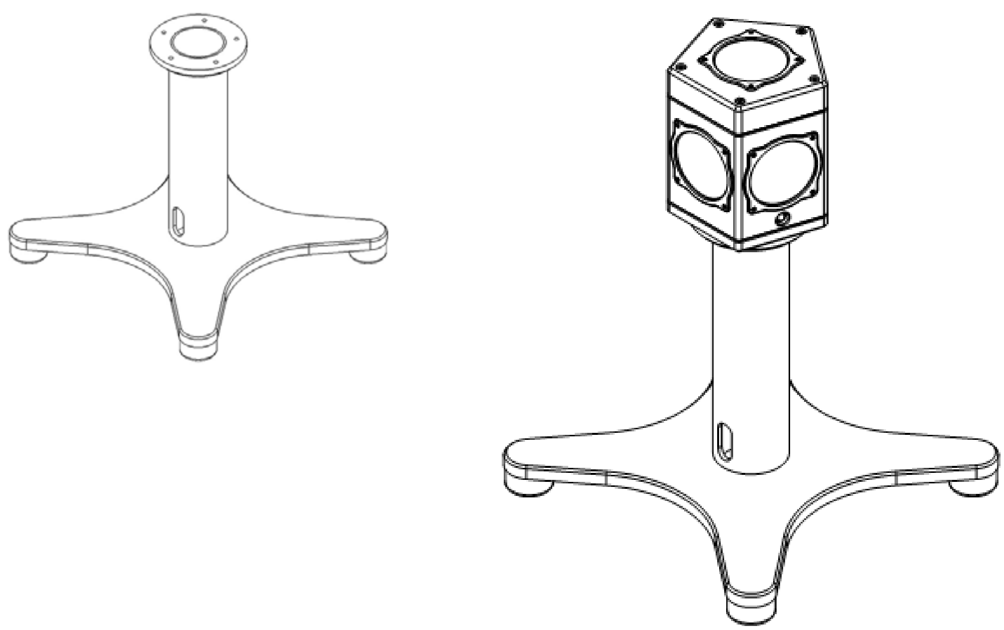

Figure 10: Ladybug3 Desktop Mount

2.5.3 Using the Tripod Adapter

The *Ladybug3* tripod adapter comes with the Development Kit, or can be purchased separately by contacting sales@ptgrey.com.

The tripod adapter consists of three parts: Base, Retainer and Gland Bushing (see drawing at left). Three gland blushings are provided: one with a pre-drilled opening and slit for use with the 1394b cable provided with the Development Kit, and two 'plain' with no slit or pre-drilled openings. Users wishing to use both a 1394b cable and a GPIO cable with the tripod adapter must drill two openings into the plain gland blushing.

Figure 11 illustrates how to assemble the tripod adapter. The drawing on the right shows a completed assembly, with the adapter connected to the base of the camera. You may need to lay the camera on its side, on a soft surface, to complete the assembly.

To create a seal between the camera and the tripod adapter, make sure the AS568A-230 *O-ring is properly fitted. For more information about the location of the O-ring, refer to* Figure 6 *in* Section 2.1*.*

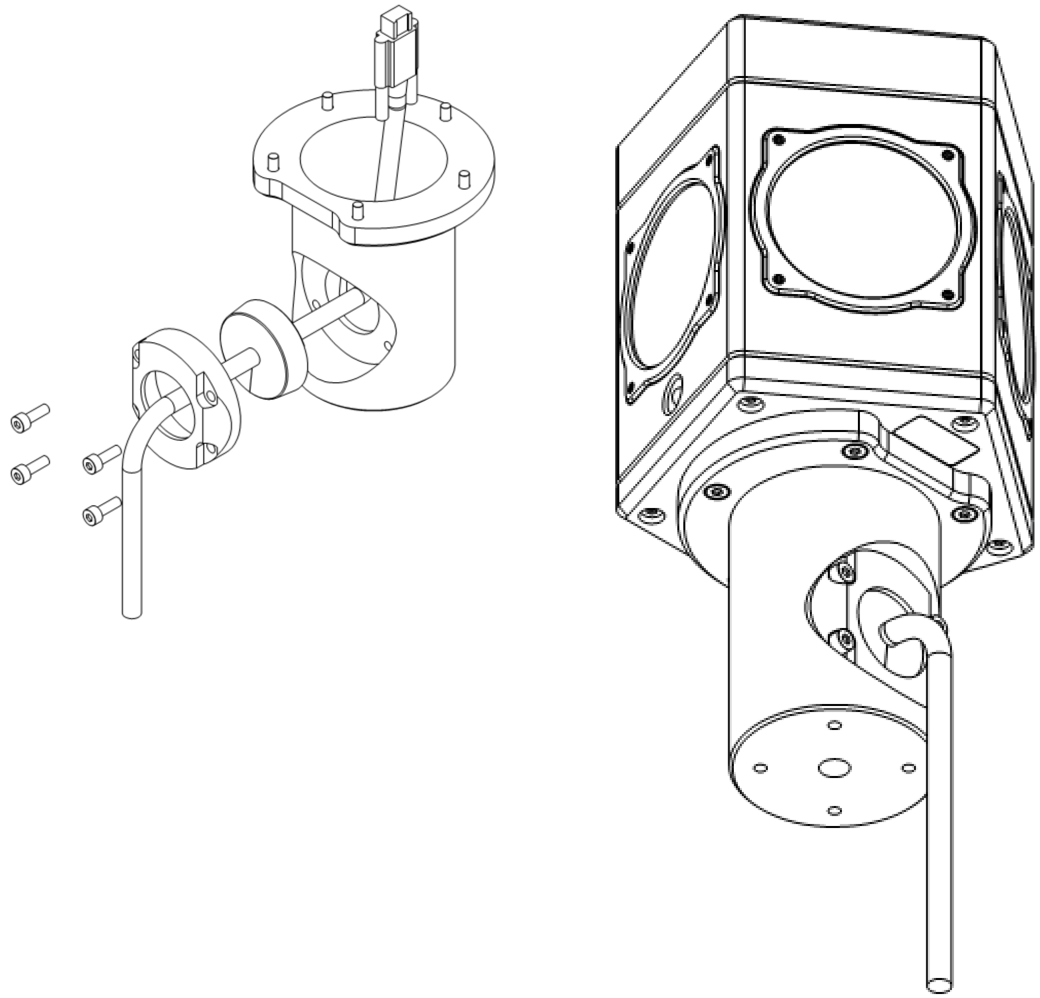

Figure 11: Assembling the Ladybug3 Tripod Adapater

2.6 Infrared Cut-Off Filters

Point Grey Research color camera models are equipped with an additional infrared (IR) cut-off filter. This filter can reduce sensitivity in the visible spectrum. The properties of this filter are illustrated in the results below, which were obtained by Point Grey Research independent of camera model.

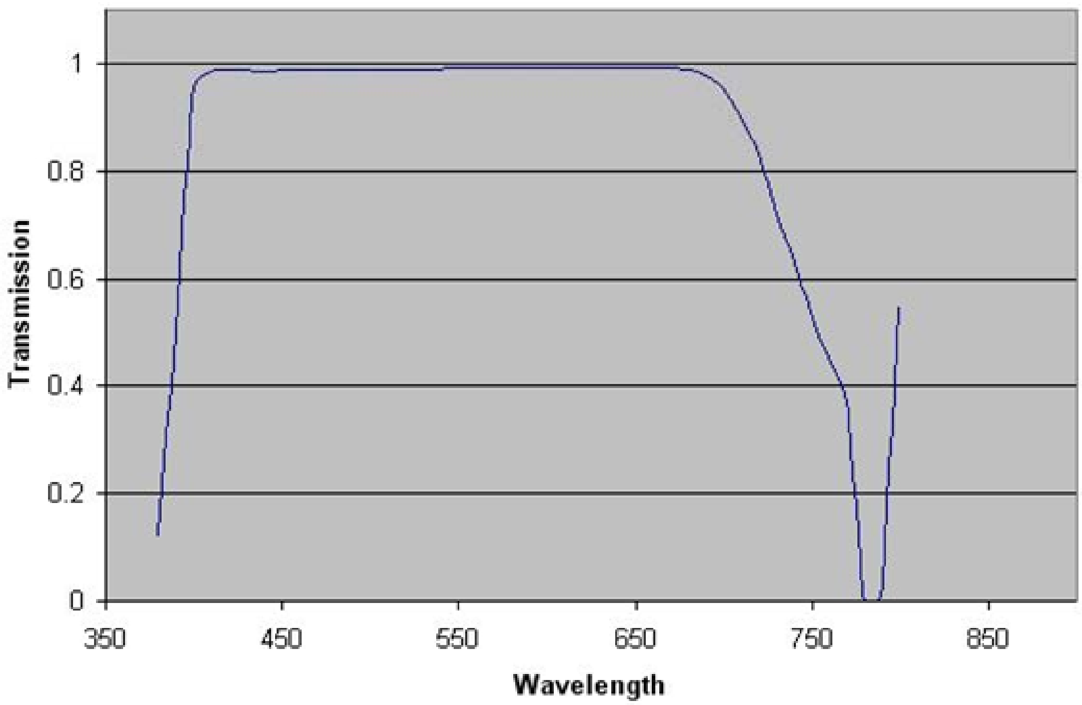

Figure 12: IR Filter Transmittance Graph

3. Camera Interface

3.1 IEEE-1394b Connector

The camera has a standard 9-pin IEEE-1394b connector (pin configuration shown below) that is used for data transmission, camera control and powering the camera. For more detailed information, consult the IEEE-1394b Standard document available from www.1394ta.org.

For a full description of the features and benefits of 1394b, refer to Knowledge Base Article 206.

While the Ladybug3 is an IEEE-1394b device, it is backward compatible with the IEEE-1394a 400Mb/s standard, and can therefore be connected to any 1394a OHCI host adapter using a 9- to 6-pin cable.

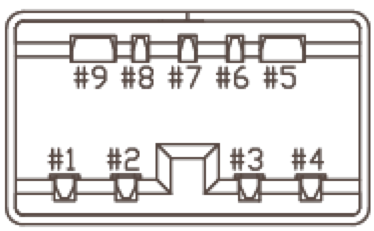

Figure 13: IEEE-1394b connector pin configuration

Pin	Signal Name	Comment
1	TPB-	Twisted Pair B (Minus)
2	TPB+	Twisted Pair B (Plus)
3	TPA-	Twisted Pair A (Minus)
4	TPA+	Twisted Pair A (Plus)
5	TPA (R)	Twisted Pair A (Reference Ground)
6	V_G	Power (Ground)
7	SC	Status Contact (Reserved for Future Use)
8	V_P	Power (Voltage)
9	TPB (R)	Twisted Pair B (Reference Ground)

Table 2: IEEE-1394b connector pin configuration

3.2 Cables

The *Ladybug3* development kit includes a 10-meter Alysium-Tech IEEE-1394b cable with locking screws. Consult the following knowledge base article for information about how to extend the physical distance between the camera and the controlling host system:

KB Article 197: http://www.ptgrey.com/support/kb/index.asp?a=4&q=197

3.3 Host Adapter Card

The *Ladybug3* development kit includes the following host adapter cards:

- 2-port FirePRO™ IEEE-1394b PCI Express host adapter card.
- IEEE-1394b ExpressCard for notebooks.

For more information regarding the differences between various 1394 host adapters, consult the following knowledge base article:

KB Article 146: www.ptgrey.com/support/kb/index.asp?a=4&q=146

3.4 Camera Power

The 9-pin 1394b interface connects to a standard IEEE-1394 (FireWire) 9-pin cable and provides a power connection between the camera and the host computer. The ideal input voltage is 12V DC; however, the camera is designed to handle voltages between 8V and 30V DC according to the IEEE 1394 standard. The power consumption is outlined in the *Camera Specifications* section.

Some systems - such as laptop computers or those with several FireWire devices connected - require an external power supply to power the camera. For this purpose, the *Ladybug3* development kit includes a 12V wall mount power supply that connects directly to the ExpressCard for notebooks, also included with the development kit. For additional information on providing power in special configurations, consult the following knowledge base article:

KB Article 93: www.ptgrey.com/support/kb/index.asp?a=4&q=93

Some PGR cameras allow the user to power-up or power-down components of the camera using the DCAM CAMERA_POWER register 0x610. The exact components, e.g. image sensor, A/D converter, other board electronics, will vary between camera models. Consult the *PGR IEEE-1394 Digital Camera Register Reference* for more information.

When a camera is power cycled (power disengaged then re-engaged), the camera will revert to its default factory settings, or if applicable, the last saved memory channel.

3.5 General Purpose Input/Output (GPIO)

The *Ladybug3* has an 8-pin GPIO connector on the bottom of the case. The connector is a Hirose HR25 8 pin connector (Mfg P/N: HR25-7TR-8SA). KIT contents include a prewired male connector; refer to the diagram below for wire color-coding. Additional male connectors (Mfg P/N: HR25-7TP-8P) can be purchased from Digikey (P/N: HR702-ND).

Diagram	Pin	Function	Function
	1	IO0	Opto-isolated Input (default Trigger in) (+3.3 V to +30 V) Input delay time: 4 μs
	2	IO1	Opto-isolated Output (default Strobe out) (+3.3 V to +30 V) Drive strength: 25 mA at 30 V
	3	IO2	Input / Output / RS232 Transmit (TX)
	4	IO3	Input / Output / RS232 Receive (RX)
	5	GND	Ground pin for bi-directional IO, Vext, +3.3 V
	6	GND	Ground pin for opto-isolated IO pins
	7	V_{EXT}	Allows the camera to be powered externally
	8	+3.3V	Power external circuitry up to 150mA

Table 3: GPIO pin assignments

Inputs can be configured to accept external trigger signals. **Outputs** can be configured to send an output signal, strobe, or PWM signal. To use the **RS232** functionality, a level converter must be used to convert the TTL digital logic levels to RS232 voltage levels. B&B Electronics (http://www.bb-elec.com/) part number 232LPTTL can be used for this conversion.

For more information on the GPIO circuitry or on using the RS232 serial port, refer to the following knowledge base articles:

Related Knowledge Base Articles

ID	Title	URL
304	New GPIO pin functionality in Flea2 FL2G-xx and Ladybug3 models	http://www.ptgrey.com/support/kb/index.asp?a=4&q=304
151	Configuring and testing the RS-232 serial port	http://www.ptgrey.com/support/kb/index.asp?a=4&q=151

3.5.1 GPIO Electrical Characteristics

The *Ladybug3* GPIO pins are TTL 3.3V pins. When configured as **inputs**, the pins are internally pulled high using weak pull-up resistors to allow easy triggering of the camera by simply shorting the pin to ground (GND). Inputs can also be directly driven from a 3.3V or 5V logic output. The inputs are protected from both over and under voltage. It is recommended, however, that they only be connected to 5V or 3.3V digital logic signals. When configured as **outputs**, each line can sink 10mA of current. To drive external devices that require more, consult the following article for information on buffering an output signal using an optocoupler:

KB Article 200: www.ptgrey.com/support/kb/index.asp?a=4&q=200

The $\mathbf{V_{EXT}}$ pin (Pin 7) allows the camera to be powered externally. The voltage limit is 8-30V, and current is limited to 1A.

The **+3.3V** pin is fused at 150mA. External devices connected to Pin 8 should not attempt to pull anything greater than that.

3.6 Status Indicator LED

LED Status	Description
Maximum red (Initial connection)	Initial startup. On until camera is initialized.
Maximum red (During operation)	Condition 1: Bus Rest. On for 0.66s. Condition 2: Power failure. On until power-up via CAMERA_POWER 0x610.
Dull Red	Configuration error.
Bright Red	Configuration error.
Dull Green	Camera is idle.
Bright Green	FireWire activity. On for 0.5s during activity.
Dull Yellow	Powered down.
Bright Yellow	Powered down + activity. On for 0.5s during activity.
Red/Green flashing	Camera firmware is being updated. Flashes at 5Hz.

Table 4: Status indicator LED descriptions

4. Camera Operations and Features

The *Ladybug3* complies with the *IIDC 1394-based Digital Camera Specification Version v1.31*.

For a complete description of the Camera Control Command Registers implemented on the *Ladybug3*, please refer to the *Point Grey Digital Camera Register Reference*, downloadable from www.ptgrey.com/support/downloads/.

4.1 General Camera Properties

The following section provides an overview of the camera properties implemented by the *Ladybug3*. Descriptions of some of the following properties and how they are implemented can be found in this *Technical Reference*. Refer to the *Point Grey Digital Camera Register Reference* for additional definitions and descriptions of:

- "Auto", "On/Off" and "One Push" - *Control and Status Registers for Features* section
- "Absolute Mode" - *Absolute Value CSR Registers* section

The following property ranges apply to a *Ladybug3* running at 15 FPS, and can change depending on the camera resolution and frame rate:

Property	Units	Min	Max	Auto	On/Off	One Push	Absolute Mode
Brightness	%	0	6.24	N	N	N	Y
Auto Exposure	EV	-7.58	2.41	Y	Y	Y	Y
White Balance	1	0	1023	N	Y	N	Y
Pan		0	5	N	N	N	Y
Shutter	ms	0.01	66.49	Y	N	Y	Y
Gain	dB	-2.25	24.00	Y	N	Y	Y
Trigger Delay	s	0	0.06	N	Y	N	Y

4.2 Frame Rates and Camera Bandwidth

This section is recommended for advanced users only, and is not meant to address all possible applications of the Ladybug3 camera.

4.2.1 Maximum Number of Cameras on a Single Bus

A single IEEE-1394 OHCI host adapter generally constitutes a single "bus". There are four elements that limit the number of cameras that can be used on the same 1394 bus:

- Although the 1394b standard limits the maximum number of simultaneous isochronous channels to 16, there is currently no host adapter that is capable of supporting 16 channels. Host adapters based on the LSI chipset such as the FirePRO™ 1394b PCI Express card can support up to 8 simultaneous DMA channels (or contexts). Host adapters based on the TI chipset can support at most 4 simultaneous DMA channels (or contexts). There are no known 1394b chipsets that allow 16 simultaneous DMA contexts. See Knowledge Base Article 146 for more information.

- The maximum bandwidth of the 1394b bus is 800Mbits/sec (10240Bytes/packet - 8000 cycles/sec). The usable bandwidth as defined by the 1394 Trade Association and enforced by the Microsoft Windows 1394 driver stack (1394bus.sys, ohci1394.sys, etc.) is approximately 80% or 80MBytes/sec (8192 bytes/packet). The remaining 20% of the bandwidth is allocated for asynchronous communication (e.g. register reads/writes). Outside of the Microsoft stack, it may be possible to allocate up to 9830 bytes/packet.

- The 1394b standard limits the maximum number of devices on a single bus to 63.
- An inadequate power supply. Consult the voltage and power requirements in the *General Specifications* section to determine the amount of power required to operate the cameras effectively.

4.2.2 Exceeding Bandwidth Limitations Using Format_7 with Multiple Cameras

There is a mechanism for effectively bypassing IEEE-1394 bus bandwidth negotiation when using cameras in Format 7 partial image mode. This functionality is useful in any situation where the user is trying to host multiple cameras on the same bus in a configuration that would normally exceed the bandwidth allocation, but where the cameras are configured to transmit data in a manner that does not exceed the total bandwidth. For additional information, see Knowledge Base Article 256.

4.2.3 Calculating Maximum Possible Frame Rate

The maximum frame rate allowable for each of the cameras on the bus depends on the resolution of the cameras and the frame rate, and can be roughly approximated using the following general formula (assuming all cameras are at the same resolution):

*Frames_per_second = (Bandwidth / (Pixels_per_frame * Bytes_per_pixel)) / Num_cameras*

Example:
To calculate the approximate frames per second available to two 7392x808 *Ladybug3s* (1616 x 6 lenses = 7392) that are in 8-bit mode, you would calculate:

Frames_per_second = (80MB/s / (7392*808*1byte/pixel)) / 2
= (80MB/s / 5.7MB/frame) / 2
= 14 FPS / 2
= 7 FPS

4.3 Format_7 Modes and Frame Rates

The *Ladybug3* captures images in Format_7 custom image mode by default. The table below outlines the Format_7 modes that are supported. The implementation of these modes and the frame rates that are possible are not specified by the IIDC, and are subject to change across firmware versions. For information about transmitting in single-image mode, see Section 4.4.10 Single Image Mode.

Note that image size is multiplied by six to account for a separate image captured by each of the camera's six sensors prior to blending and stitching. Additionally, Mode 1, Mode 3 and Mode 7 produce four separate images for each Bayer color channel.

Mode 2 and Mode 3 are half-height modes, which are generated through a color binning process. Refer to the *Binning in Format_7* section for information on mode implementation.

Changing the size of the image or the pixel encoding format requires an undetermined length of frame times, including the stop/start procedure, tearing down/reallocating image buffers, write times to the camera, etc.

Mode	Pixel Format	Max Size (bytes) (H x V)*	Min BPP (Max Size)	Max BPP (Max Size)	Max FPS
0	Raw8	1616 x 1232 x 6	408	9792	6.5
1**	Mono8 Color-separated	808 x 616 x 4 x 6	408	9792	tbd
2	Raw8 Half-height	1616 x 616 x 6	408	9792	13
3	Mono8 Color-separated Half-height JPEG-compressed	808 x 308 x 4 x 6	408	9792	32
6**	Raw8 JPEG-compressed	1616 x 1232 x 6	408	9792	tbd
7	Mono8 Color-separated JPEG-compressed	808 x 616 x 4 x 6	408	9792	16

* Ladybug CCDs are arranged in "portrait" orientation to increase the vertical field of view. As a result, height measurements appear as width in the Ladybug SDK, and width measurements appear as height.

**Modes 1 and 6 are not supported in the Ladybug SDK.

Table 5: Supported partial image (Format 7) video formats and modes for LB3-20S4C

In Format_7 mode, the PAN register 884h specifies the order in which images are transmitted from each camera on the system, in increasing order beginning with the camera specified. For example, 884h = 82000002h specifies that images are transmitted beginning with camera 2, in the following order: 2, 3, 4, 5, 0, 1. On the Ladybug3 in Mode 0 and Mode 2, stitching does not behave as expected when the specified camera != 0. We recommend maintaining the PAN value to specify camera 0 (default setting).

Related Knowledge Base Articles

ID	Title	URL
264	Overview of multithreading optimizations in Ladybug library	http://www.ptgrey.com/support/kb/index.asp?a=4&q=264
288	Ladybug2's JPEG image quality and buffer usage settings	http://www.ptgrey.com/support/kb/index.asp?a=4&q=288

4.3.1 Determining Format_7 Frame Rates and Image Sizes

4.3.1.1 Determining Frame Rate

The theoretical frame rate (FPS) that can be achieved given the number of packets per frame (PPF) can be calculated as follows:

$$FPS = \frac{1}{\text{Packets per Frame} * 125us}$$

An estimate for the number of packets per frame can be determined according to the following:

$$PPF = \frac{\text{Image\_Size} * \text{Bytes\_Per\_Pixel}}{\text{Bytes\_Per\_Packet}}$$

For the exact number of packets per frame, query the PACKET_PER_FRAME_INQ register; for the number of bytes per packet, query the BYTE_PER_PACKET register.

For example, assuming a Format 3 image size of 7392x808, JPEG compressed pixel format (1 byte per pixel), and 9792 bytes per packet, the calculation would be as follows:

FPS = 1 / ((7392*808*1 / 9772) * 0.000125)
FPS = 1 / (611 * 0.000125)
FPS = 13.16

An interactive bandwidth calculator is available in [Knowledge Base Article 22](). It can be used to calculate approximate bandwidth requirements for various IIDC modes.

4.3.1.2 Determining Image Size

As another example, assume we want to achieve 16 FPS in Format 7 mode (Mono8, color-separated, JPEG compressed), and we want to determine which image size to specify. The calculation would be as follows:

$$\text{Image Size} = \frac{\text{Bytes per Packet}}{\text{FPS} * \text{Bytes per Pixel} * 125us}$$

Image Size = 9792 / (16 * 1 * 0.000125)
Image Size = 4896000

If horizontal size is set at 808, height is determined as 4896000 / 808 = 6059. This figure should be multiplied by 0.95 to allow bandwidth for asynchronous communication needs. The resulting height may then be set at 5756 pixels.

4.3.2 Binning in Format_7

The read-only FORMAT_7_RESIZE_INQ register at 0x1AC8 contains information pertinent to the current Format_7 mode such as whether standard or Bayer binning is being performed on the image.

For more detailed information on the FORMAT_7_RESIZE_INQ register, please see the *Point Grey Digital Camera Register Reference*.

4.4 Image Acquisition

4.4.1 Camera Power

The *Ladybug3* allows the user to power-up or power-down components of the camera using the CAMERA_POWER register 0x610. The exact components, e.g. image sensor, A/D converter, other board electronics, will vary between camera models. By default, power is OFF both at startup and reinitialization.

If isochronous transmit (ISO_EN / ONE_SHOT / MULTI_SHOT) is enabled while the camera is powered down, the camera will automatically write *Cam_Pwr_Ctrl* = 1 to power itself up. However, disabling isochronous transmit does not automatically power-down the camera.

The camera will typically not send the first two images acquired after power-up. The auto-exposure algorithm does not run while the camera is powered down. It may therefore take several (*n*) images to get a satisfactory image, where *n* is undefined.

4.4.2 Shutter

The *Ladybug3* supports automatic, manual and one-push control of the CCD shutter time. The shutter can be programmed to open in ranges from 0.01ms to 4.2 s in extended shutter mode. Shutter times are scaled by the divider of the basic frame rate. For example, dividing the frame rate by two (e.g. 15 FPS to 7.5 FPS) causes the maximum shutter time to double (e.g. 66ms to 133ms).

Formulas for converting the fixed point (relative) shutter values reported by SHUTTER register 0x81C to floating point (absolute) values are not provided. Users wishing to work with real-world values should refer to the *Absolute Value CSR Registers* section of the *Point Grey Digital Camera Register Reference*.

The terms “integration” and “exposure” are often used interchangeably with “shutter”.

The time between the end of shutter for consecutive frames will always be constant. However, if the shutter time is continually changing (e.g. shutter is in Auto mode being controlled by Auto Exposure), the time between the beginning of consecutive integrations will change. If the shutter time is constant, the time between integrations will also be constant.

The *Ladybug3* will continually expose and read image data off of the sensor as long as the camera is powered.

Shutter can be controlled on each of the six *Ladybug3* sensors independently. For more information, see Section 4.4.6.

4.4.3 Gain

The *Ladybug3* supports automatic, manual and one-push gain modes. The A/D converter provides a PxGA gain stage (white balance / preamp) and VGA gain stage (GAIN register 0x820). The main VGA gain stage is available to the user, and is variable from 0 to 24dB in steps of 0.046db.

Formulas for converting the fixed point (relative) gain values reported by GAIN register 0x820 to floating point (absolute) values are not provided. Users wishing to work with real-world values should refer to the *Absolute Value CSR Registers* section of the *Point Grey Digital Camera Register Reference*.

Increasing gain also increases image noise, which can affect image quality. To increase image intensity, try adjusting the shutter time first.

Gain can be controlled on each of the six *Ladybug3* sensors independently. For more information, see Section 4.4.6.

4.4.4 JPEG Compression and JPEG Buffer Usage

When the camera operates in a JPEG-compressed imaging mode, the compressor unit processes image data based on a specified compression rate. Although specifying a higher JPEG quality value produces higher-quality images, more data must accumulate in the image buffer on the PC, increasing the risk of buffer overflow errors.

When JPEG compression is set to auto mode, compression quality adjusts automatically to the following parameters:

- The maximum allowed by the size of the image buffer on the PC. Image buffer size is determined by the current Format_7 imaging settings.
- Auto-buffer usage. This setting is the percentage of the image buffer that is used for image data, and is configurable when JPEG compression is in auto mode. Specifying a value less than the maximum (100%) allows for room in the buffer to accommodate extra images, depending on scene variations from frame to frame. A setting between 80%-95% is recommended. The visual improvement in compression quality that results from a setting higher than 95% is negligible compared to the increased amount of data generated.

Specifying auto-JPEG compression is recommended, as this setting ensures that compression quality continually adjusts so that the JPEG buffer usage does not exceed the image buffer size.

The following registers are used to control JPEG compression and buffer usage. For information about how to control these registers using the LadybugCapPro application, see Knowledge Base Article 288 (http://www.ptgrey.com/support/kb/index.asp?a=4&q=288).

JPEG_CTRL: 1E80h

Specifies the compression rate of the camera when operating in a JPEG-compressed mode.

Format:

Field	Bit	Description
Presence_Inq	[0]	Presence of this feature 0: N/A 1: Available
	[1-5]	Reserved
ON_OFF	[6]	JPEG compression ON_OFF for format_7 mode 0,1,2,3. If the Format_7 mode is 6 or 7, this bit is ignored. Read: Read the status Write: Set 0: JPEG compression is OFF 1: JPEG compression is ON If this bit = 0, other fields are read only
A_M_Mode	[7]	Read: Read a current mode Write: Set the mode 0: Manual, 1: Automatic JPEG quality control
	[8-23]	Reserved
Value	[24-31]	JPEG quality value. Valid range: 0x01(1%) to 0x64(100%). A value of 0 is treated as 60%. A write to this value in 'Auto' mode is ignored.

JPEG_BUFFER_USAGE: 1E84h

Specifies the percentage of the image buffer on the PC that is used for JPEG compressed image data, when the camera is operating in a JPEG mode.

Format:

Field	Bit	Description
Presence_Inq	[0]	Presence of this feature 0: N/A 1: Available
	[1-24]	Reserved
Value	[25-31]	Value. Valid range: 0x00 (0%) to 0x7F (100%) A value of 0 is treated as 0x66 (80%). On Ladybug3 firmware v1.2.2.1 or later, a value of 0 is treated as 0x72 (90%).

4.4.5 Auto Exposure

Auto exposure (AE) allows the camera to automatically control shutter and/or gain in order to achieve a specific average image intensity, and is controlled using the AUTO_EXPOSURE register 0x804. There are three AE states:

State	Description
Off	Control of the exposure is achieved via setting shutter and/or gain.
On Manual AE	The camera automatically modifies shutter and/or gain to try and match the average image intensity to one-quarter of the specified AE value.
On Auto AE	The camera modifies the AE value in order to produce an image that is visually pleasing.

If only one of shutter and gain is in auto mode, the auto exposure controller attempts to control the image intensity using that one parameter. If both of these parameters are in auto mode, the auto exposure controller uses a shutter-before-gain heuristic to try and maximize the signal-to-noise ratio by favoring a longer shutter time over a larger gain value.

Auto exposure can be controlled on each of the six *Ladybug3* sensors independently. For more information, see Section 4.4.6.

4.4.5.1 Managing the Auto Exposure Algorithm

The auto exposure controller can be adjusted so that only certain sensors on the camera system are used to calculate the settings of the auto exposure algorithm. For example, auto exposure settings can be adjusted to factor in data from the five sensors on the side of the camera (sensors [0 – 4], while excluding data from the sensor on the top of the camera (sensor [5]).

Controlling which sensors contribute to auto exposure calculations can be achieved using the following methods:

- The LadybugCap and LadybugCapPro Demo programs. For more information, refer to the Ladybug SDK Help.
- The AE_STATS_MASK register, described below.

AE_STATS_MASK: 1E90h

> *This register is not documented in the Point Grey Digital Camera Register Reference.*

Allows the user to specify which sensors are used when collecting statistics for the auto exposure algorithm. Setting all of bits [26 – 31] to OFF (0) is equivalent to all of bits [26 – 31] set to ON (1). Any of bits [26 – 31] that are set to ON (1) must have image transmission from corresponding sensors enabled in IMAGE_SELECTION register 1E88h; otherwise, the value is ignored. For information about IMAGE_SELECTION register 1E88h, see Knowledge Base Article 320.

Format:

Field	Bit	Description
Presence_Inq	[0]	Presence of this feature 0: Not available 1: Available
	[1-25]	Reserved
Use_sensor_0	[26]	Use sensor [0] 0: Not used 1: Used
Use_sensor_1	[27]	Use sensor [1] 0: Not used 1: Used
Use_sensor_2	[28]	Use sensor [2] 0: Not used 1: Used
Use_sensor_3	[29]	Use sensor [3] 0: Not used 1: Used
Use_sensor_4	[30]	Use sensor [4] 0: Not used 1: Used
Use_sensor_5	[31]	Use sensor [5] 0: Not used 1: Used

4.4.6 Independent Sensor Control of Shutter, Gain and Auto Exposure

The Independent Sensor Control feature provides customized control of exposure for each of the six cameras on the *Ladybug3* camera system independently. This feature allows users to acquire images with greater dynamic range of the overall scene.

Independent Sensor Control provides independent control of exposure-related features only. This feature does not encompass other camera control settings such as gamma or white balance.

Independent Sensor Control is activated by turning off the SHUTTER 81Ch or GAIN 820h controls of the camera system. When these controls are off, the following options are available:

- When either shutter or gain is off, auto exposure can be controlled manually or automatically for each camera on the system by using the SUB_AUTO_EXPOSURE_* control and status registers (CSRs), described below;

  OR:

- When gain is off, gain can be controlled manually or automatically for each camera on the system using the SUB_GAIN_* CSRs, described below. When shutter is off, shutter can be controlled manually or automatically using the SUB_SHUTTER_* CSRs, described below.

INDEPENDENT_CONTROL_INQ: 1E94h

This register gives the quadlet offset of the base address of the SUB_SHUTTER_*, SUB_GAIN_* and SUB_AUTO_EXPOSURE_* CSRs. It is currently set to 1B00h.

Format:

Offset	Name	Bit	Description
1E94h	INDEPENDENT_CONTROL_INQ	[0..31]	Quadlet offset of the Independent Sensor Control CSRs.

Current Independent Sensor Control Offsets

Offset	Name	Field	Bit	Description
1B00h	SUB_GAIN_0	Presence_Inq	[0]	Presence of this feature 0: Not available, 1: Available
			[1-5]	Reserved
		ON_OFF	[6]	Write: ON or OFF for this feature Read: read a status 0: OFF, 1: ON If this bit = 0, other fields are read only. This bit is shared across all SUB_GAIN_* registers; it cannot be set independently. Setting this bit effectively sets the equivalent bit of Gain CSR 820h to the inverse value, and vice versa. Setting this bit effectively sets the equivalent bit of the Sub_Auto_Exposure_* CSRs to the inverse value.
		A_M_Mode	[7]	Write: set the mode Read: read a current mode 0: Manual, 1: Automatic
			[8-19]	Reserved
		Value	[20-31]	Gain value of Camera_0. A write to this field in ‘Auto’ mode is ignored.
1B04h	SUB_SHUTTER_0	Presence_Inq	[0]	Presence of this feature 0: Not available, 1: Available
			[1-5]	Reserved

		ON_OFF	[6]	Write: ON or OFF for this feature Read: read a status 0: OFF, 1: ON If this bit = 0, other fields are read only. This bit is shared across all SUB_SHUTTER_* registers; it cannot be set independently. Setting this bit effectively sets the equivalent bit of Shutter CSR 81Ch to the inverse value, and vice versa. Setting this bit sets the equivalent bit of the Sub_Auto_Exposure_* CSRs to the inverse value.
		A_M_Mode	[7]	Write: set the mode Read: read a current mode 0: Manual, 1: Automatic
			[8-19]	Reserved
		Value	[20-31]	Shutter value of Camera_0. A write to this field in 'Auto' mode is ignored.
1B08h	SUB_AUTO_EXPOSURE_0	Presence_Inq	[0]	Presence of this feature 0: Not available, 1: Available
		-	[1-5]	Reserved
		ON_OFF	[6]	Write: ON or OFF for this feature Read: read a status 0: OFF, 1: ON If this bit = 0, other fields are read only. This bit is shared across all SUB_AUTO_EXPOSURE_* registers; it cannot be set independently. Setting this bit effectively sets the equivalent bits of SUB_SHUTTER_* and SUB_GAIN_* CSRs to the inverse value.
		A_M_Mode	[7]	Write: set the mode Read: read a current mode 0: Manual, 1: Automatic
			[8-19]	Reserved
		Value	[20-31]	Auto exposure value of Camera_0. A write to this field in 'Auto' mode is ignored.
1B20h	SUB_GAIN_1	Same format as SUB_GAIN_0		
1B24h	SUB_SHUTTER_1	Same format as SUB_SHUTTER_0		
1B28h	SUB_AUTO_EXPOSURE_1	Same format as SUB_AUTO_EXPOSURE_0		
1B40h	SUB_GAIN_2	Same format as SUB_GAIN_0		
1B44h	SUB_SHUTTER_2	Same format as SUB_SHUTTER_0		

1B48h	SUB_AUTO_EXPOSURE_2	Same format as SUB_AUTO_EXPOSURE_0
1B60h	SUB_GAIN_3	Same format as SUB_GAIN_0
1B64h	SUB_SHUTTER_3	Same format as SUB_SHUTTER_0
1B68h	SUB_AUTO_EXPOSURE_3	Same format as SUB_AUTO_EXPOSURE_0
1B80h	SUB_GAIN_4	Same format as SUB_GAIN_0
1B84h	SUB_SHUTTER_4	Same format as SUB_SHUTTER_0
1B88h	SUB_AUTO_EXPOSURE_4	Same format as SUB_AUTO_EXPOSURE_0
1BA0h	SUB_GAIN_5	Same format as SUB_GAIN_0
1BA4h	SUB_SHUTTER_5	Same format as SUB_SHUTTER_0
1BA8h	SUB_AUTO_EXPOSURE_5	Same format as SUB_AUTO_EXPOSURE_0

4.4.7 Automatic Inter-Camera Synchronization

Multiple Point Grey FireWire cameras, when they are on the same IEEE-1394 bus and running at the same frame rate, are automatically synchronized to each other at the hardware level. When using multiple cameras, the timing of one camera to another camera is as follows:

- If the cameras are on the same bus, the cameras are synchronized to within 125μs (microseconds) of each other (note: 125μs is the maximum deviation). However, the 1394 bandwidth limits the maximum number of cameras that can be on one bus. See the section *Maximum Number of Cameras on a Single 1394 Bus* for more information.

- If the cameras are on separate buses, use PointGrey's *MultiSync*™ software to synchronize the cameras across buses. This can be used to synchronize cameras on different buses within the same computer or on different buses across multiple computers. The software will ensure that the cameras are synchronized to within 125μs. If Multisync is not running, there is no timing correlation between separate cameras on separate buses.

It is possible to offset the synchronization of individual cameras relative to other cameras using the TRIGGER_DELAY register 0x834.

Related Knowledge Base Articles

ID	Title	URL
274	Overview of Ladybug2 automatic inter-camera synchronization feature	http://www.ptgrey.com/support/kb/index.asp?a=4&q=274

4.4.8 Frame Rate Control

The current base frame rate is controlled using the CURRENT_FRAME_RATE register 0x600. The *Ladybug3* allows users to further "fine-tune" the frame rates of their cameras using the FRAME_RATE register 0x83C, which is described in detail in the *Point Grey Digital Camera Register Reference*. This is particularly useful for capturing an image stream at a different frame rate than those outlined in the *Supported Data Formats and Modes* section, and can be useful for synchronizing to 50Hz light sources, which can cause image intensity fluctuations due to the light source oscillations being out of sync with the frame rate.

4.4.9 High Dynamic Range (HDR) Mode

The *Ladybug3* can be set into a High Dynamic Range mode in which the camera will rotate between 4 user-defined shutter and gain settings. This allows images representing a wide range of shutter and gain settings to be collected in a short time to be combined into a final HDR image later. The *Ladybug3* does not create the final HDR image; this must be done by the user. The PGR Ladybug SDK includes the *LadybugCaptureHDRImage* sample program. This sample illustrates how to use the Ladybug API to capture images in HDR mode.

The format of the HDR registers is as follows:

Offset	Register	Remarks
0x1800	HDR control register	Toggle bit [6] to enable/disable HDR
0x1820	HDR shutter register for image 0	Similar to SHUTTER register 0x81C
0x1824	HDR gain register for image 0	Similar to GAIN register 0x820
0x1840	HDR shutter register for image 1	Similar to SHUTTER register 0x81C
0x1844	HDR gain register for image 1	Similar to GAIN register 0x820
0x1860	HDR shutter register for image 2	Similar to SHUTTER register 0x81C
0x1864	HDR gain register for image 2	Similar to GAIN register 0x820
0x1880	HDR shutter register for image 3	Similar to SHUTTER register 0x81C
0x1884	HDR gain register for image 3	Similar to GAIN register 0x820

Please note that the on/off bit (bit [6]) for the HDR shutter and gain registers is hard-coded to ON.

Related Knowledge Base Articles

ID	Title	URL
116	Capturing HDR Images with Ladybug and Ladybug2	http://www.ptgrey.com/support/kb/index.asp?a=4&q=116

4.4.10 Single Image Mode

The Ladybug3 can be configured to operate in a format/mode that transmits images from only one camera on the system. The following formats/modes are available:

- 800x600 Y8: Format_1, Mode 2
- 800x600 Y16: Format_1, Mode 6
- 1600x1200 Y8: Format_2, Mode 5
- 1600x1200 Y16: Format_2, Mode 7

When configured in one of these single image modes, use bits 29-31 of the PAN register 884h to specify the camera from which to transmit images. For example, 884h = 82000002h specifies image transmission from camera 2.

Alternatively, the IMAGE_SELECTION register 1E88h can be used to transmit individual, color-separated images when the camera is operating in a Format_7 (default) color-separated mode.

IMAGE_SELECTION: 1E88h

Specifies the transmission of individual images from the camera to the PC when operating in Format_7 (default) mode.

Format:

Field	Bit	Description
Presence_Inq	[0]	Presence of this feature 0: N/A 1: Available
	[1-7]	Reserved
Image_En	[8-31]	Enables transmission of individual images. Refer to the table below for a breakdown of images by bit. Write: Transmission enabled or disabled Read: Read a status 0: Transmission disabled, 1: Transmission enabled The default value is 000000h, and is interpreted as a value of 888888h when the camera is operating in a mode that does not produce 4 separate Bayer-channel images from each sensor, or FFFFFFh when the camera is operating in a mode that produces 4 separate Bayer channel images from each sensor. In other words, all images are transmitted. A mask of 888888h is applied whenever the camera is operating in a mode that does not produce separate Bayer-channel images.

Format of Transmit_Enabled field:

Field	Bit	Description
Transmit_Enabled	[8]	Camera 0, Bayer channel 0
	[9]	Camera 0, Bayer channel 1
	[10]	Camera 0, Bayer channel 2
	[11]	Camera 0, Bayer channel 3
	[12]	Camera 1, Bayer channel 0
	[13]	Camera 1, Bayer channel 1
	[14]	Camera 1, Bayer channel 2
	[15]	Camera 1, Bayer channel 3
	[16]	Camera 2, Bayer channel 0
	[17]	Camera 2, Bayer channel 1
	[18]	Camera 2, Bayer channel 2
	[19]	Camera 2, Bayer channel 3
	[20]	Camera 3, Bayer channel 0
	[21]	Camera 3, Bayer channel 1
	[22]	Camera 3, Bayer channel 2
	[23]	Camera 3, Bayer channel 3
	[24]	Camera 4, Bayer channel 0
	[25]	Camera 4, Bayer channel 1
	[26]	Camera 4, Bayer channel 2

	[27]	Camera 4, Bayer channel 3
	[28]	Camera 5, Bayer channel 0
	[29]	Camera 5, Bayer channel 1
	[30]	Camera 5, Bayer channel 2
	[31]	Camera 5, Bayer channel 3

4.5 Image Processing

4.5.1 Accessing Raw Bayer Data

Users must access the raw Bayer data to apply their own color conversion algorithm or one of the algorithms in the Ladybug SDK. Images should be acquired using one of the Format_7 video modes that support Raw8 pixel encoding.

The actual physical arrangement of the red, green and blue "pixels" is determined by the arrangement of the color filter arrays on the imaging sensor itself. The format (i.e. order) in which this raw color data is streamed out depends on the specific camera model and firmware version. This format can be queried using the BAYER_TILE_MAPPING register 0x1040 that is implemented on all PGR cameras.

Raw image data can be accessed programmatically via the pData pointer in the LadybugImage structure (e.g. LadybugImage.pData). In Raw8 modes, the first byte represents the pixel at (row 0, column 0), the second byte at (row 0, column 1), etc. In the case of a *Ladybug3* that is streaming Raw8 image data in RGGB format, if we access the image data via the pData pointer we have the following:

- pData[0] = Row 0, Column 0 = red pixel (R)
- pData[1] = Row 0, Column 1 = green pixel (G)
- pData[1616] = Row 1, Column 0 = green pixel (G)
- pData[1617] = Row 1, Column 1 = blue pixel (B)

Related Knowledge Base Articles

ID	Title	URL
33	Different color processing algorithms.	www.ptgrey.com/support/kb/index.asp?a=4&q=33
37	Writing color processing software and color interpolation algorithms.	www.ptgrey.com/support/kb/index.asp?a=4&q=37
89	How is color processing performed on my camera's images?	www.ptgrey.com/support/kb/index.asp?a=4&q=89

4.5.2 White Balance

The *Ladybug3* supports white balance, which is a system of color correction to deal with differing lighting conditions. Adjusting the white balance by modifying the relative gain of R, G and B in an image enables white areas to look "whiter". Taking some subset of the target image and looking at the relative red to green and blue to green response, the general idea is to scale the red and blue channels so that the response is 1:1:1. The white balance scheme outlined in the IIDC specification states that blue and red are adjustable and that green is not. The blue and red values can be controlled using the WHITE_BALANCE register 0x80C.

4.5.3 Embedded Image Information

The *Ladybug3* has a feature that allows image timing and camera settings information to be embedded in the first several pixels of each image. This feature is controlled using the FRAME_INFO register 0x12F8, which is described in detail in the *Point Grey Digital Camera Register Reference*.

4.6 Camera and Device Control

4.6.1 Programmable Strobe Output

The *Ladybug3* is capable of outputting a strobe pulse off one or all of its GPIO pins. By default, a pin that is configured to be a strobe output will output a pulse each time the camera begins integration of an image. Setting a strobe duration value of zero will produce a strobe pulse indicating the exposure (shutter) time.

The *Ladybug3* can also be configured to output a variable strobe pulse pattern. The strobe pattern functionality allows users to define the frames for which the camera will output a strobe. For example, this is useful in situations where a strobe should only fire:

- Every Nth frame (e.g. odd frames from one camera and even frames from another); or
- N frames in a row out of T (e.g. the last 3 frames in a set of 6); or
- Specific frames within a defined period (e.g. frames 1, 5 and 7 in a set of 8)

Related Knowledge Base Articles

ID	Title	URL
179	Setting a GPIO pin to output a signal using DCAM v1.31 strobe functionality	www.ptgrey.com/support/kb/index.asp?a=4&q=179
207	Setting a GPIO pin to output a strobe signal pulse pattern	www.ptgrey.com/support/kb/index.asp?a=4&q=207
212	GPIO strobe signal continues after isochronous image transfer stops	www.ptgrey.com/support/kb/index.asp?a=4&q=212

4.6.2 RS-232 Serial Port

The *Ladybug3* is capable of serial communications at baud rates up to 115.2Kbps via the on-board logic level serial port built into the camera's GPIO connector. To use this functionality, a level converter must be used to convert the TTL digital logic levels to RS-232 voltage levels. B&B Electronics (http://www.bb-elec.com/) part number 232LPTTL can be used for this conversion.

Related Knowledge Base Articles

ID	Title	URL
151	Configuring and testing the RS-232 serial port	www.ptgrey.com/support/kb/index.asp?a=4&q=151

4.6.3 Memory Channel Storage of Camera Settings

The *Ladybug3* has the ability to save and restore camera settings and imaging parameters via on-board memory channels. This is useful for saving default power-up settings, such as gain, shutter, video format and frame rate, etc., that are different from the factory defaults.

Memory channel 0 is used for the default factory settings that users can always restore to. The *Ladybug3* provides two additional memory channels for custom default settings. The camera will initialize itself at power-up, or when explicitly reinitialized, using the contents of the last saved memory channel. Attempting to save user settings to the (read-only) factory defaults channel will cause the camera to switch back to using the factory defaults during initialization.

Refer to the *Memory Channel Registers* section in the Appendix for a full listing of all registers saved.

Memory channels are configured using the following registers, which are described in detail in the *Point Grey Digital Camera Register Reference*: MEMORY_SAVE 0x618; MEM_SAVE_CH 0x620; and CUR_MEM_CH 0x624.

4.6.4 Camera Upgrades

The firmware on the *Ladybug3* can be upgraded or downgraded to later or earlier versions using the UpdatorGUI program that is bundled with every firmware version available from www.ptgrey.com/support/downloads/. The latest firmware versions often include significant bug fixes and feature enhancements that may benefit some users. To determine the changes made in a specific firmware version, consult the Release Notes. For more information on updating camera firmware, consult the *UpdatorGUI User Manual* available in the downloads section.

Appendix A: Memory Channel Registers

Register Name	Offset
CURRENT_FRAME_RATE	600h
CURRENT_VIDEO_MODE	604h
CURRENT_VIDEO_FORMAT	608h
CAMERA_POWER	610h
CUR_SAVE_CH	620h
BRIGHTNESS	800h
AUTO_EXPOSURE	804h
SHARPNESS	808h
WHITE_BALANCE	80Ch
HUE	810h
SATURATION	814h
GAMMA	818h
SHUTTER	81Ch
GAIN	820h
IRIS	824h
FOCUS	828h
TRIGGER_MODE	830h
TRIGGER_DELAY	834h
FRAME_RATE	83Ch
PAN	884h
TILT	888h
ABS_VAL_AUTO_EXPOSURE	908h
ABS_VAL_SHUTTER	918h
ABS_VAL_GAIN	928h
ABS_VAL_BRIGHTNESS	938h
ABS_VAL_GAMMA	948h
ABS_VAL_TRIGGER_DELAY	958h
ABS_VAL_FRAME_RATE	968h
IMAGE_DATA_FORMAT	1048h
AUTO_EXPOSURE_RANGE	1088h
AUTO_SHUTTER_RANGE	1098h
AUTO_GAIN_RANGE	10A0h
GPIO_XTRA	1104h
SHUTTER_DELAY	1108h
GPIO_STRPAT_CTRL	110Ch
GPIO_CTRL_PIN_x	1110h, 1120h, 1130h, 1140h
GPIO_XTRA_PIN_x	1114h, 1124h, 1134h, 1144h
GPIO_STRPAT_MASK_PIN_x	1118h, 1128h, 1138h, 1148h
FRAME_INFO	12F8h
FORMAT_7_IMAGE_POSITION	008h
FORMAT_7_IMAGE_SIZE	00Ch
FORMAT_7_COLOR_CODING_ID	010h
FORMAT_7_BYTE_PER_PACKET	044h

Appendix B: Glossary

Term	Definition
1394a	An Institute of Electrical and Electronics Engineers (IEEE) interface standard capable of transferring data at a rate of 400Mbit per second.
1394b	An IEEE interface standard capable of transferring data at a rate of 800Mbit per second.
Absolute Values	Real-world values, such as milliseconds (ms), decibels (dB) or percent (%). Using the absolute values is easier and more efficient than applying complex conversion formulas to integer values.
Analog-to-Digital Converter	Often abbreviated as ADC or A/D converted, it is a device that converts a voltage to a digital number.
API	Application Programming Interface. Essentially a library of software functions.
Asynchronous Transmission	The transfer of image data from the camera to the PC that is regulated by an external signal, such as a trigger. Asynchronous transfers do not guarantee when data will be transferred. However, they do guarantee that data will arrive as sent. Asynchronous transfers may be used when data integrity is a higher priority than speed. An example might be an image data transfer to a printer, where speed is less critical than getting the image pixels correct. Asynchronous transfers are initiated from a single node, designated the ‘requestor’, to or from the address space of another node, designated the ‘responder’. Asynchronous requests are packet-based. The requestor node generates a request packet that the 1394 bus sends to the responder node. The responder node is responsible for handling the request packet and creating a response packet that is sent back to the requestor node to complete a single transfer. There are three types of 1394 asynchronous transfers: Read, Write and Lock.
BPP	Bytes per packet. An image is broken into multiple packets of data, which are then streamed isochronously to the host system. Each packet is made up of multiple bytes of data.
Brightness (%)	This is essentially the level of black in an image. A high brightness will result in a low amount of black in the image. In the absence of noise, the minimum pixel value in an image acquired with a brightness setting of 1% should be 1% of the A/D converter’s minimum value.
Config ROM	Configuration read-only memory. A section of memory dedicated to describing low-level device characteristics such as Model and Vendor ID, IEEE-1394 version compliance, base address quadlet offsets, etc.
Color Processing	Also known as ‘interpolation,’ an algorithm for converting raw Bayer-tiled image data into full color images. Depending on camera model, this process takes place either on-camera or on the PC. For more information, refer to Knowledge Base Article 33.
DCAM	Abbreviation for the *IIDC 1394-based Digital Camera (DCAM) Specification*, which is the standard used for building FireWire-based cameras.
Dynamic Range	The difference between the maximum and minimum amounts of light that a sensor can measure. This is bounded on the upper end by the maximum charge that any pixel can contain (sensor full well depth) and at the lower end by the small charge that every sensor spontaneously generates (read noise).
Exposure (EV)	This is the average intensity of the image. It will use other available (non-manually adjustable) controls to adjust the image.
Firmware	Programming that is inserted into programmable read-only memory, thus becoming a permanent part of a computing device. Firmware is created and tested like software and can be loaded onto the camera.
Format_7	Encompasses partial or custom image video formats and modes, such as region of interest of pixel binned modes. Format_7 modes and frame rates are defined by the camera manufacturer, as opposed to the DCAM specification.
FPS	Frames Per Second.
Frame Rate	Often defined in terms of number of frames per second (FPS) or frequency (Hz). This is the speed at which the camera is streaming images to the host system. It basically defines the interval between consecutive image transfers.
Gain (dB)	The amount of amplification that is applied to a pixel by the A/D converter. An increase in gain can result in a brighter image and an increase in noise.
Gamma	Gamma defines the function between incoming light level and output picture level. Gamma can also be useful in emphasizing details in the darkest and/or brightest regions of the image.
GPIO	General Purpose Input/Output.

Grabbing Images	A commonly-used phrase to refer to the process of enabling isochronous transfers on a camera, which allows image data to be streamed from the camera to the host system.
Hz	Hertz. A unit of frequency; one Hertz has a periodic interval of one second. Often used interchangeably with FPS as a measure of frame rate.
Isochronous Transmission	The transfer of image data from the camera to the PC in a continual stream that is regulated by an internal clock. Isochronous transfers on the 1394 bus guarantee timely delivery of data. Specifically, isochronous transfers are scheduled by the bus so that they occur once every 125µs. Each 125µs timeslot on the bus is called a frame. Isochronous transfers, unlike asynchronous transfers, do not guarantee the integrity of data through a transfer. No response packet is sent for an isochronous transfer. Isochronous transfers are useful for situations that require a constant data rate but not necessarily data integrity. Examples include video or audio data transfers. Isochronous transfers on the 1394 bus do not target a specific node. Isochronous transfers are broadcast transfers which use channel numbers to determine destination.
Lookup Table	A matrix of gamma functions for each color value of the current pixel encoding format.
Node	An addressable device attached to a bus. Although multiple nodes may be present within the same physical enclosure (module), each has its own bus interface and address space and may be reset independently of the others.
Node ID	A 16-bit number that uniquely differentiates a node from all other nodes within a group of interconnected buses. Although the structure of the node ID is bus-dependent, it usually consists of a bus ID portion and a local ID portion. The most significant bits of the node ID are the same for all nodes on the same bus; this is the bus ID. The least-significant bits of the node ID are unique for each node on the same bus; this is called the local ID. The local ID may be assigned as a consequence of bus initialization.
One Push	For use when a control is in manual adjust mode, One Push sets a parameter to an auto-adjusted value, then returns the control to manual adjust mode.
PHY	Physical layer. Each 1394 PHY provides the interface to the 1394 bus and performs key functions in the communications process, such as bus configuration, speed signaling and detecting transfer speed, 1394 bus control arbitration, and others.
Pan	A mechanism to horizontally move the current portion of the sensor that is being imaged. In stereo and spherical cameras, Pan controls which individual sensors transmit images.
Pixel Clock	The rate at which the sensor outputs voltage signals in each pixel from the optical input.
Pixel Format	The encoding scheme by which color or greyscale images are produced from raw image data.
Quadlet	A 4 byte (32-bit) value.
Quadlet Offset	The number of quadlets separating a base address and the desired CSR address. For example, if the base address is 0xFFFFF0F00000 and the value of the quadlet offset is 0x100, then the actual address offset is 0x400 and the actual adress 0xFFFFF0F00400.
Register	A term used to describe quadlet-aligned addresses that may be read or written by bus transactions.
Saturation	This is how far a color is from a gray image of the same intensity. For example, red is highly saturated, whereas a pale pink is not.
SDK	Software Development Kit
Sharpness	This works by filtering the image to reduce blurred edges.
Shutter	A mechanism to control the length of time the sensor is exposed to light from the image field for each frame. In milliseconds (ms), it is the amount of time that the shutter stays open, also known as the *exposure* or *integration* time. The shutter time defines the start and end point of when light falls on the imaging sensor. At the end of the exposure period, all charges are simultaneously transferred to light-shielded areas of the sensor. The charges are then shifted out of the light shielded areas of the sensor and read out.
Signal-to-Noise Ratio (dB)	The difference between the ideal signal that you expect and the real-world signal that you actually see is usually called noise. The relationship between signal and noise is called the signal-to-nose ratio (SNR). SNR is calculated using the general methodology outlined in Knowledge Base Article 142.
SXGA	1280x1024 pixel resolution
Tilt	A mechanism to vertically move the current portion of the sensor that is being imaged.
Trigger	A signal to which the acquisition of images by the camera is synchronized. Triggers can be from an outside electrical source (external) or software-generated (internal).
UXGA	1600x1200 pixel resolution
VGA	640x480 pixel resolution
White Balance	A method to enable white areas of an image to appear correctly by modifying the gain of red and blue channels relative to the green channel. White balance can be used to accommodate differing lighting conditions.
XVGA	1024x768 pixel resolution

Appendix C: Technical Support Resources

Point Grey Research Inc. endeavors to provide the highest level of technical support possible to our customers. Most support resources can be accessed through the Product Support section of our website: www.ptgrey.com/support.

Creating a Customer Login Account

The first step in accessing our technical support resources is to obtain a Customer Login Account. This requires a valid name, e-mail address, and camera serial number. To apply for a Customer Login Account go to www.ptgrey.com/support/downloads/.

Knowledge Base

Our on-line knowledge base at www.ptgrey.com/support/kb/ contains answers to some of the most common support questions. It is constantly updated, expanded, and refined to ensure that our customers have access to the latest information.

Product Downloads

Customers with a Customer Login Account can access the latest software and firmware for their cameras from our downloads site at www.ptgrey.com/support/downloads. We encourage our customers to keep their software and firmware up-to-date by downloading and installing the latest versions.

Contacting Technical Support

Before contacting Technical Support, have you:

1. *Read the product documentation and user manual?*
2. *Searched the Knowledge Base?*
3. *Downloaded and installed the latest version of software and/or firmware?*

If you have done all the above and still can't find an answer to your question, contact our Technical Support team at www.ptgrey.com/support/contact/.

Appendix D: Contacting Point Grey Research

For any questions, concerns or comments please contact us via the following methods:

Email:	For all general questions about Point Grey Research please contact us at info@ptgrey.com. For technical support (existing customers only) contact us at http://www.ptgrey.com/support/contact/.
Knowledge Base:	Find answers to commonly asked questions in our knowledge base at http://www.ptgrey.com/support/kb/.
Downloads:	Users can download the latest manuals and software from http://www.ptgrey.com/support/downloads/

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China	LUSTER LightVision Tech. Co., Ltd (www.lusterlighttech.com)
Singapore Malaysia Thailand	Voltrium Systems Pte Ltd. (www.voltrium.com.sg)
Taiwan	Apo Star Co., Ltd. (www.apostar.com.tw)

Appendix E: Revision History

Revision	Date	Notes
1.1	December 17, 2008	• Updated dimensional drawings in Sections 2.1 and 2.2. • Added information about O-ring seal in Section 2.4.1. • Added signal to noise ratio measurement to Section 1.3. • Added spectral response curve diagram to Section 1.3.1.
1.2	February 27, 2009	• Updated Recommended Requirements in Section 1.4 and removed Minimum Requirements. • Sections 1.1 and 1.3: Clarified focal length of microlenses is 3.3 mm. • Updated Appendix B: Glossary
1.3	May 22, 2009	• Glossary: Fixed error in 1394b definition. • Added information about the tripod adapter, including description and dimensions, and assembly instructions. • Clarified that maximum shutter speed in extended shutter mode is 4.2 s. • Power input voltage range is 8-30 V.
1.4	September 11, 2009	• Added parallax measurements to Section 1.3 Camera Specifications. • Section 3.5 General Purpose Input/Output (GPIO): Corrected GPIO pinout to show proper function of GND pins. Added reference to knowledge base for GPIO circuitry.
1.5	February 11, 2010	• Added Section 4.4.10 Single Image Mode • Added information about the PAN register to Section 4.4.10 and Section 4.3 Format_7 Modes and Frame Rates. • Section 4.4.4 Auto Exposure Added section on independent sensor control of auto exposure algorithm.
1.6	September 16, 2010	• Section 2.3: Tripod Adapter Description and Dimensions: Updated drawing with mounting hole thread size corrected from 1/4-20 to 3/8-16. • Section 1.3: Camera Specifications: Added focus distance.
1.7	February 2, 2011	• Added Section 4.4.6 Independent Sensor Control of Shutter, Gain and Auto Exposure.
1.8	March 8, 2011	• Added Section 4.4.4 JPEG Compression and JPEG Buffer Usage. • Section 4.4.10 Single Image Mode: Added IMAGE SELECTION register 1E88h.

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