Flea

Technical Reference Manual

Revised 6/15/2004

Hardware Warranty

Point Grey Research Inc. (PGR) 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, PGR 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 PGR, have been found to have failed due to customer abuse, mishandling, alteration, improper installation or negligence.

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1. Introduction

The *Flea* IEEE-1394 boxed camera is Point Grey Research's most compact IEEE-1394 digital camera, designed to fit spaces as small as 30x31mm. With a 1/3" Sony CCD and a 12-bit analog to digital converter, the camera delivers high quality images ideal for demanding imaging applications.

This manual attempts to provide the user with additional information beyond that provided in the *Flea Getting Started Manual*. If you are unable to find the information you are looking for in this manual, please consult the *Flea Getting Started Manual* or the *PGR IEEE-1394 Digital Camera Register Reference*.

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 (see section 5.4 *Contacting Technical Support*).

> ***NOTE:*** *All model-specific information presented in this manual reflects functionality available in the latest version of camera firmware.*

1.1. DCAM Compliance

The *Flea* line of IEEE-1394 cameras complies with the *IIDC 1394-based Digital Camera (DCAM) Specification Version v1.31*.

All *Flea* models currently implement the frame rate, trigger, parallel input/output (PIO), serial input/output (SIO) and strobe functionality outlined in the *IIDC 1394-based Digital Camera (DCAM) Specification Version v1.31*. To determine the specific DCAM v1.31 features that are implemented in your *Flea*, consult the following sections of the *PGR IEEE-1394 Digital Camera Register Reference*.

- Inquiry Registers for Basic Functions
- Inquiry Registers for Feature Presence
- Inquiry Registers for Feature Elements

1.2. Camera Control Command Registers

For a complete description of the Camera Control Command Registers implemented on the *Flea*, please refer to the *PGR IEEE-1394 Digital Camera Register Reference*.

1.3. General Specifications

Specification	Low Resolution (640x480)	High Resolution (1024x768)
Style	Small format boxed camera	
Sensor	Sony 1/3" Type Sony HAD CCD	
	ICX424	ICX204
Resolution	640x480	1024x768
A/D Converter	Analog Devices AD9849 A/D	
Video Output Signal	8 bits per pixel / 12 bits per pixel digital data	
Interfaces	6-pin IEEE-1394 for camera control and video data transmission 4 general purpose digital input/output pins	
Voltage Requirements	8-32V	
Power consumption	Less than 3W	
Frame Rates	3.75, 7.5, 15, 30, 60fps	1.875, 3.75, 7.5, 15, 30fps
Gain	Automatic/Manual modes at 0.035dB resolution	
	0 to 27dB	0 to 24dB
Shutter	Automatic/Manual/Extended Shutter modes	
	20µs to 16ms @ 60Hz	20µs to 66ms @ 15Hz
Signal To Noise Ratio	Greater than 55dB or better at minimum gain	
External Trigger	DCAM v1.31 Trigger_Mode_0	
Dimensions	30mm x 31mm x 29 mm (the length of the camera does not include optics or connectors)	
Mass	46 grams (without lens)	
Lens Adapter	C- or CS-mount lens	
Camera Specification	IIDC 1394-based Digital Camera Specification v1.31	
FCC & CE Compliance	Complies with Part 15 Class B of FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference; and (2) this device must accept any interference received, including interference that may cause undesired operation. The device also complies with CE requirements.	
Operating Temp	Commercial grade electronics rated from 0° - 45°C	
Storage Temperature	Room temperature	
Camera Upgrades	Firmware upgradeable in field via IEEE-1394 interface.	
Current Firmware	0.9 Release Candidate 10	

1.4. Camera Power

The 6-pin 1394 connector connects to a standard IEEE-1394 (FireWire) 6-pin cable and provides the camera with both power and a connection to your computer. The ideal input voltage is 12V DC; however, the camera is designed to handle voltages between 8V and 32V DC according to the IEEE 1394 standard. The power consumption of the *Flea* is less than 3W.

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 PGR cameras, which require a 6-pin connector (the additional two pins provide power). Some 1394 accessory manufacturers sell cables that have one 4-pin end and one 6-pin end. However, the cameras still require power to be

provided. For suggestions on how to provide power in these circumstances, consult the knowledge base article at http://www.ptgrey.com/support/kb/details.asp?id=93.

1.5. Sensors

The *Scorpion* is currently available with one of four Sony HAD interline transfer, progressive scan CCDs.

The following table enumerates a variety of features of these sensors and provides links to locations of pertinent data sheets:

n/a = information not available in datasheet

	Low Resolution (640x480)	**High Resolution (1024x768)**
Sensor Type	Sony ICX424AL Sony ICX424AQ	Sony ICX204AL Sony ICX204AK
Sensor Size	Diagonal 6mm (1/3" type)	Diagonal 6mm (1/3" type) (effective 5.952mm)
Total Pixels	692(H) x 504(V) approx. 350K pixels	1077(H) x 788(V) approx. 850K pixels
Total Effective Pixels	659(H) x 494(V) approx. 330K pixels	1034(H) x 779(V) approx. 800K pixels
Active Pixels	640(H) x 480(V) approx. 307K pixels	1024(H) x 768(V) approx 790K pixels
Chip Size	5.79mm(H) x 4.89mm(V)	5.80mm(H) x 4.92mm(V)
Unit Cell Size	7.4um(H) x 7.4um(V)	4.65um(H) x 4.64um(V)
Datasheets	Datasheets for the above sensors can be found at http://ptgrey.com/support/kb/details.asp?id=23	

1.5.1. Typical Spectral Response

The spectral response curves for each sensor are in the technical datasheets available from the individual sensor manufacturers. Datasheets for these sensors can be found at http://ptgrey.com/support/kb/details.asp?id=23.

1.6. Infrared Cut-Off Filters

It should be noted that *Flea* cameras equipped with color sensors have an additional infrared cut-off filter included. The approximate properties of this filter are illustrated by the IRC30 curve in the graph below.

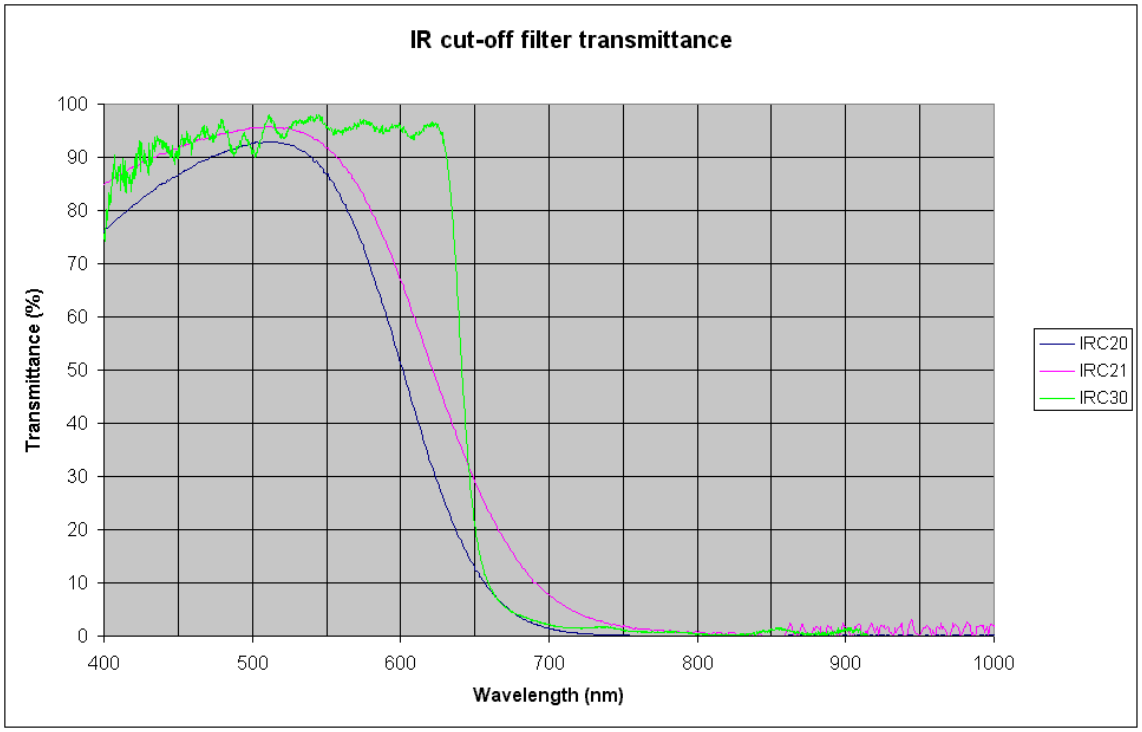

Table 1: IR cut-off filter transmittance graph

1.7. Analog-to-Digital Converter

The *Flea* incorporates an Analog Devices AD9849AKST A/D converter in order to digitize the images produced by the CCD. The following table illustrates the most important aspects of the processor. For more information, please refer to the Analog Devices website at http://www.analog.com/.

Resolution	12-bit, 30MHz
Description	The AD9849 is a highly integrated CCD signal processor for digital still camera applications. It includes a complete analog front end with A/D conversion, combined with a programmable timing driver. The Precision Timing core allows adjustment of high-speed clocks with approximately 1 ns resolution.
Pixel Gain Amplifier	4dB +/- 6dB 6-bit
Variable Gain Amplifier	2dB to 36dB 10-bit
Black Level Clamp	0 LSB to 255 LSB

2. Camera Operations and Features

2.1. Frame Rate Increases with Regions of Interest

The *Flea* implements a DCAM Format 7 customizable video format and mode (see section *Customizable Formats and Modes* for camera-specific information) that allows for faster frame rates based on selecting a specific region of interest (ROI) of the image. The ROI feature allows you to specify a portion of the CCD imager array to be processed and transmitted by the camera to the PC. By reducing the image resolution to a specific subset of the total image, the amount of data being sent along the IEEE-1394 bus can also be reduced and the total number of frames per second can be increased.

2.2. Extended Shutter Times

The maximum shutter time for some *Scorpion* models can be extended beyond the normal shutter range by turning the FRAME_RATE register OFF. To do this, set the *ON_OFF* field of the FRAME_RATE register 83Ch to OFF. Once the FRAME_RATE is turned off, you should see the *Max_Value* of the ABS_VAL_SHUTTER register 910h increase. The FRAME_RATE register was introduced in version 1.31 of the DCAM. See the *PGR IEEE-1394 Digital Camera Register Reference* for more information.

> ***NOTE:*** *The maximum extended shutter time reported by the SHUTTER_INQ register 51Ch is capped at 4095 (0xFFF), the maximum value allowed by the* Max_Value *field of this register. Use the value in the* Max_Value *field of the ABS_VAL_SHUTTER register to determine the maximum allowable shutter time.*

Model	Format and FPS	Min (ms)	Max (ms)	Notes
Low resolution (640x480)	640x480, 60fps	0.02	1978.75	
	640x480, 30fps	0.04	3957.50	
	640x480, 15fps	0.04	7915.00	
	640x480, 7.5fps	0.15	15830.00	
	640x480, 3.75fps	0.15	31660.00	
	640x480, 1.875fps	0.15	63320.00	
High resolution (1024x768)	1024x768, 30fps	0.02	2637.69	
	1024x768, 15fps	0.03	5276.67	
	1024x768, 7.5fps	0.06	10553.33	
	1024x768, 3.75fps	0.12	21106.67	
	1024x768, 1.875fps	0.24	42213.33	

Table 2: Extended shutter minimum and maximum times

2.3. Automatic Inter-Camera Synchronization

Multiple *Flea* units on the same IEEE-1394 bus 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 (please note: 125µs is the maximum deviation). However, the 1394 bandwidth limits the maximum number of cameras that can be on one bus.
- If the cameras are on separate buses, a *PGR Sync Unit* is needed to synchronize the cameras across buses. The *Sync Unit* can synchronize cameras on different buses within the same computer, or on different buses across multiple computers. This device will ensure that the cameras are synchronized to within 125µs. If there is no sync device, there is no timing correlation between separate cameras on separate buses.

2.4. Timestamp and Camera Settings Embedded in Image

The *Flea* implements a useful feature that allows image timing and camera settings information to be embedded in the first several pixels of each image. The first byte of embedded image data starts at pixel 0,0 (column 0, row 0) and continues in the first row of the image data i.e. (1,0), (2,0), etc. This feature is enabled via the FRAME_TIMESTAMP register 12F8h (see the *PGR IEEE-1394 Digital Camera Register Reference* for more information on this register).

Users using color cameras and doing Bayer color processing on the PC must extract the value from the non-color processed image in order for the data to be valid.

2.5. Supported Data Formats and Modes

2.5.1. Standard Formats, Modes and Frame Rates

The following sections enumerate the different non-Format 7 data formats and modes contained in the IEEE-1394 specification that are supported by the *Flea*. See section *Customizable Formats and Modes* for supported Format 7 modes.

Camera	Format	Mode	Frame Rate (fps)							Mode Description
			1.875	3.75	7.5	15	30	60	120	
Lo-res (640x480)	0	5	•	•	•	•	•	•		640x480 Y8 (Mono)
	0	6	•	•	•	•	•			640x480 Y16 (Mono 16)
Hi-res (1024x768)	1	5	•	•	•	•	•			1024x768 Y8 (Mono)
	1	6					•			800x600 Y16 (Mono 16)
	1	7	•	•	•	•				1024x768 Y16 (Mono 16)

Table 3: Supported video formats, modes and frame rates

2.5.2. Customizable Formats and Modes

The table below outlines IEEE-1394 DCAM-compliant Format 7 custom image modes that are supported by the camera. However, the frame rates specified are not contained in the specification.

Format 7, Mode 0 is a region of interest (sub-window) mode that allows the user to only transmit a selected area of the image. Moving the position of region of interest to a different location does not require the camera to be stopped (isochronous transmission disabled) and restarted (iso enabled). However, changing the size of the ROI does require the stop/start procedure.

Format 7, Mode 1 is a sub-sampled mode that uses 2x2 pixel binning to achieve faster frame rates.

Format 7, Mode 2 is another sub-sampled mode that uses 1x2 pixel binning to achieve faster frame rates.

Camera	Format	Mode	Max Image Size (HxV)	Unit Size (H,V)	Notes
Lo-res (640x480)	7	0	640x480	16,16	Increased frame rate ▪ 100fps, 320x240 ▪ 122fps, 160x160
	7	1	320x240	16,16	2x2 pixel binning ▪ 100fps, 320x240
	7	2	640x240	16,16	1x2 pixel binning ▪ 100fps, 640x240
Hi-res (1024x768)	7	0	1024x768	16,16	Increased frame rate ▪ 42fps , 640x480 ▪ 62fps, 320x240 ▪ 73fps, 160x160
	7	1	512x384	16,16	2x2 pixel binning ▪ 50fps, 512x384
	7	2	1024x384	16,16	2x2 pixel binning ▪ 50fps, 1024x384

Table 4: Supported partial image (Format 7) video formats and modes

3. Application Notes

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

3.1. Maximum Number of Cameras on a Single 1394 Bus

There are four elements that limit the number of cameras that can be used on the same 1394 bus:

1. Although the 1394 standard limits the maximum number of simultaneous isochronous channels to 16, there is currently no OHCI Compliant IEEE-1394 host controller that is capable of supporting 16 channels. Host adapters based on the TI chipset can support at most 4 simultaneous DMA channels (also known as DMA contexts). Similar adapters based on the Lucent/Agere chipset support up to 8 DMA contexts.
2. The maximum bandwidth of the 1394 bus is 400Mbits/sec. The actual usable bandwidth is approximately 80% or 40MBytes/sec.
3. The 1394.a standard limits the maximum number of devices on a single bus to 63.
4. Consult the voltage and power requirements in the *General Specifications* section of this manual to determine the amount of power required to operate the cameras effectively.

3.1.1. 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[1] 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 frames per second available to three 1024x768 *Scorpions* that are in 8-bit mode, you would calculate:

Frames_per_second = (40MB/s / (1024*768*1byte/pixel)) / 3
= (40MB/s / 0.75MB/total_frames) / 3
= 53.33fps / 3
= 17.8fps

[1] To determine the exact frame rate allowable, use the number of quadlets being sent at the given frame rate (see *Isochronous Bandwidth Requirements* in the *PGR IEEE-1394 Digital Camera Register Reference*).

3.1.2. Problems Maximizing Frame Rates

In some circumstances, due to 1394 bus bandwidth limitations set by Microsoft Windows, some cameras may not be able to achieve the maximum calculated frame rate.

Example:
According to the formula in the section *Calculating Maximum Possible Frame Rate* it is possible to run four 640x480 cameras in Y8 (8-bit) mode at 60Hz. However, when attempting to do this via the PGR software *Format and Frame Rate* controls, starting the fourth camera at 60Hz often results in a "maximum bandwidth exceeded" error.

The workaround to this problem is to circumvent the Windows bandwidth restrictions by directly manipulating the camera's CURRENT_FRAME_RATE register 600h to set the cameras to 60Hz (600h = A0000000h (FrameRate_4)).

3.2. Using the Camera in Single Shot Mode

It is possible to put the camera into a mode where it will grab only a single image (single-shot) or a set number of images (multi-shot).

In order to have the camera capture a single image, the user must do the following:

- Put the software system into a mode where it is ready to accept images from the camera. If you are using the PGR FlyCapture software, this will require calls to flycaptureInitialize() and flycaptureStart().
- Ensure that isochronous data transfer is turned off by doing the following:

  set 614h to 00 00 00 00

- For a single shot, poke the first bit of the MULTI_SHOT register as follows:

  set 61Ch to 80 00 00 00

- For multiple shots (in this example 175, or 0xAF), poke the first bit of the MULTI_SHOT register as follows:

  set 61Ch to 40 00 00 AF

This will cause the camera to produce the desired number of images before resuming a wait state. Standard image transmission can be resumed by poking the 614h register again as follows:

set 614h to 80 00 00 00

3.3. Interacting with External Devices

The Point Grey Research *Flea* is a versatile IEEE-1394 digital camera that is capable of interacting with external devices. It can be configured to trigger on an external electrical signal or

produce a similar signal that allows devices external to the camera to be synchronized to the camera. Input and output of these signals is achieved via the *Flea's* general-purpose IO pins described in the Flea Getting Started Manual, downloadable from http://www.ptgrey.com/support/downloads/.

3.3.1. External trigger timing information

For most *Flea* models the time from the external trigger going low to the integration time is shown below:

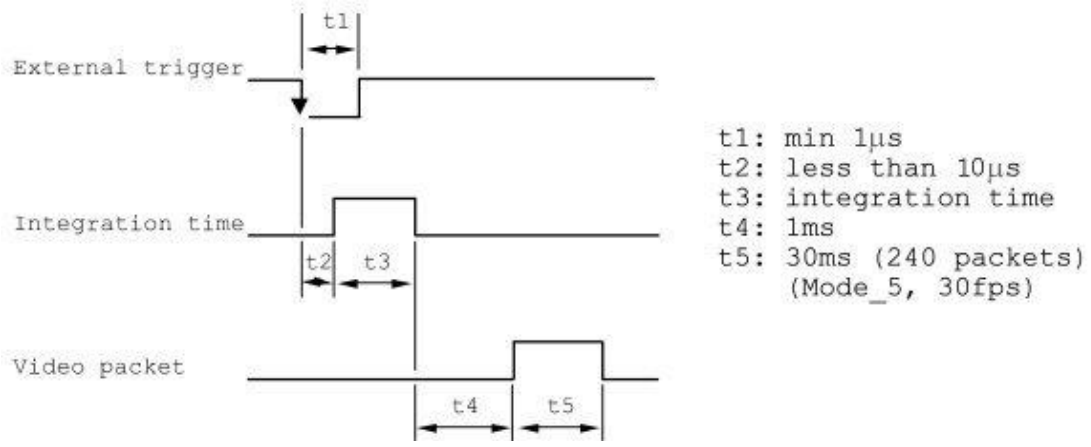

Figure 1: *Flea* timing characteristics

3.3.2. Synchronizing to an external device (Trigger Mode)

To learn more about how to configure the *Flea* to acquire images synchronized to an external electrical signal, please consult *Technical Application Note TAN2004004*, downloadable from http://www.ptgrey.com/support/downloads/.

3.3.3. Broadcasting a sync pulse to an external device

To learn more about how to configure the *Flea* to output a strobe pulse of fixed duration, please consult *Technical Application Note TAN2004004*, downloadable from http://www.ptgrey.com/support/downloads/.

3.3.4. Configuring and testing the RS-232 serial port

To learn more about how to configure and test the RS-232 serial port functionality for the *Flea*, please consult *Technical Application Note TAN2004001*, downloadable from http://www.ptgrey.com/support/downloads/.

3.3.5. Use Trigger_Mode_1 to control integration time

To see the effects of using Trigger_Mode_1 to control the camera shutter time:

1. Attach a function generator to the camera - negative to GND pin, positive to the GPIO pin currently configured as the trigger source.
2. Attach an oscilloscope to the camera (just to observe the signal and duty cycle) - ground the GND and signal lead to the trigger source pin.
3. Open the PGR FlyCapture SDK example program, FlyCap, and start the camera
4. Open the Camera Control Dialog box and go to the Extended tab
5. Enable External Trigger mode - the function generator's pulses should now be driving the external trigger
6. Enable Trigger_Mode_1 by writing 82 01 00 00 to register 830h
7. Use the function generator to increase and decrease the duty cycle. Decreasing the duty cycle increases the integration (shutter) time, and vice versa.

3.4. Working with Y16 (16-bit Mono) Images

Most *Flea* models can output Y16 (16 bits per pixel) mono images. However, not all 16 bits of data are useable; only 10 bits contain useable data.

3.4.1. Y16 (Mono 16) Data Format

The data format for Y16 images is DCAM-compliant.

Description	**Data Format**	
Actual bit depth: 10bpp	0-7	8-15
Bit alignment: MSB Byte alignment: Big-endian	High Byte	Low Byte

Table 5: Y16 (16-bit Mono) data format

3.4.2. Saving a Y16 (Mono 16) Image

The PGM file format can be used to correctly save 16-bit images. Following is some sample code that can be used in conjunction with the PGR FlyCapture SDK:

```
FILE* fileImage = fopen( "image16.pgm", "wb" );
fprintf( fileImage, "P5\n" ); // PGM magic id value
fprintf( fileImage, "%d %d\n", image.iCols, image.iRows );
fprintf( fileImage, "%d\n", 0xFFFF ); // max value of a 16bit pixel

unsigned short* pPixel = (unsigned short*)image.pData;
for( int iPixel = 0; iPixel < image.iRows * image.iCols; iPixel++ )
{
       fwrite( pPixel, 1, 2, fileImage );
```



```
            pPixel++;
        }
```

There are very few photo manipulation/display applications that can correctly display true 16-bit images. XV in Linux and Adobe Photoshop are two possibilities.

4. Errata and Change Notifications

This errata section lists significant changes to the *Flea* hardware and electrical components that have been implemented since the last release of the *Flea Technical Reference*. For a summary of all firmware changes, please consult the *Flea* Firmware Release Notes.

[No errata to list at this time]

5. Technical Support Resources

Point Grey Research Inc. endeavours 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: http://www.ptgrey.com/support.

5.1. 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: http://www.ptgrey.com/support/downloads/user_request.html.

5.2. Knowledge Base

Our on-line knowledge base contains answers to some of the most common support questions. It has information about all PGR products and was developed to help customers resolve product issues. It is constantly updated, expanded, and refined to ensure that our customers have access to the latest information. To access the knowledge base, go to: http://www.ptgrey.com/support/kb/.

5.3. Product Downloads

Customers with a Customer Login Account can access the latest software and firmware for their cameras from our downloads site at http://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. These versions include the latest bug fixes and feature enhancements.

5.4. 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 using our on-line web form: http://www.ptgrey.com/support/contact/. This will create a ticket in our Request Tracker support system, and a Technical Support representative will contact you by e-mail within one (1) business day.

6. Contacting Point Grey Research Inc.

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

Email:

For all general questions about Point Grey Research or our products contact info@ptgrey.com.

For all specific questions about our products or for quotes or product pricing contact sales@ptgrey.com.

For technical support (existing customers only) please consult the *Technical Support Resources* section of this manual.

Telephone:

(604) 242-9937
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Or, visit our webpage http://www.ptgrey.com for detailed product information and support.

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