Flea® 2

Technical Reference Manual

Version 1.10
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Point Grey Research® Inc.
12051 Riverside Way • Richmond, BC • Canada • V6W 1K7 • **T** (604) 242-9937 • **www.ptgrey.com**

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 two (2) years. 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.

Trademarks

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1 Introduction

1.1. Flea2 Overview

The ultra-compact and versatile *Flea2* is designed as an end-to-end cost effective and reliable IEEE-1394b solution for demanding imaging applications such as semiconductor inspection and high-speed assembly. It was developed for easy design transition from the original *Flea* camera. At 29x29x30mm, the *Flea2* is even smaller than the original Flea camera and is designed to have the form factor of similar industry standard analog cameras. The 800Mb/s interface enables full frame rate RGB image transmission and even more cameras on the same bus, and the IEEE-1394b cable with jack screws allows a more secure connection to the camera.

Users are encouraged to download TAN2006005 from www.ptgrey.com/products/flea2 for detailed information on how to transition applications from the *Flea* to the *Flea2*. 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 ***1.2.2.00****.*

To check the camera firmware version, consult our knowledge base: www.ptgrey.com/support/kb/index.asp?a=4&q=9.

1.1.1. Image Acquisition

Feature	Description
IEEE-1394b Bandwidth	800Mb/s interface allows full color RGB output at high data rates
Automatic Synchronization	Multiple Flea2's on the same 1394b bus automatically sync
Programmable Exposure	User-programmable shutter, gain, and black clamp settings via software
Fast Frame Rates	Faster standard frame rates plus pixel binning and ROI support
Multiple Trigger Modes	Bulb-trigger mode, multiple triggered exposures before readout
Trigger at Full Frame Rate	Overlapped trigger input, image acquisition and transfer

1.1.2. Image Processing

Feature	Description
Color Conversion	On-camera conversion to YUV411, YUV422 and RGB formats
Image Processing	On-camera control of sharpness, hue, saturation, gamma, LUT
Image Flip / Mirror	Horizontal image flip (mirror image)
Embedded Image Info	Pixels contain frame-specific info (e.g. shutter, 1394 cycle time)
Test Pattern	Continuous static image for testing and development

1.1.3. Camera and Device Control

Feature	Description
Auto White Balance	Auto and one-push white balance for easy color balancing
Frame Rate Control	Fine-tune frame rates for video conversion (e.g. PAL @ 24 FPS)
Improved Strobe Output	Increased drive strength, configurable strobe pattern output
RS-232 Serial Port	Provides serial communication via GPIO TTL digital logic levels
Memory Channels	Non-volatile storage of camera default power-up settings
Broadcast Properties	Apply settings (e.g. shutter, gain) to all cameras on the same bus
Voltage Sensor	Monitors sensor voltages to ensure optimal image quality
Camera Upgrades	Firmware upgradeable in field via IEEE-1394 interface.

1.1.4. Mechanics and Form Factor

Feature	Description
Ultra-Compact Design	Small (29mm x 29mm x 30mm) and light (58g)
Industry Standard Mechanics	ASA/ISO-compliant mounting bracket and C-mount lens holder
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 *Flea2* 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/:

- *PGR IEEE-1394 Digital Camera Register Reference*
- *PGR FlyCapture User Manual*
- *TAN2004004: Synchronizing to an external signal using DCAM 1.31 Trigger Mode_0*
- *TAN2004001: Configuring and testing the RS-232 serial port*
- *TAN2005002: Setting a GPIO pin to strobe using DCAM 1.31 Strobe Signal Output*
- *TAN2005003: Setting a GPIO pin to output a strobe signal pulse pattern*
- *TAN2005004: Buffering a GPIO pin output signal to drive an external device*
- *TAN2006005: Transitioning from the Flea® to the Flea®2: A How-To Guide*

1.3. Camera Specifications

Specification	03S2	08S2	14S3	20S4	13S2	50S5
Overview	Ultra-compact case-enclosed IEEE-1394b digital camera					
Imaging Sensor	Sony® progressive scan CCDs					
Sensor Model	ICX424 1/3"	ICX204 1/3"	ICX267 1/2"	ICX274 1/1.8"	ICX445 1/3"	ICX655 2/3"
Sensor Max Pixels	648x488	1032x776	1392x1032	1624x1224	1288x964	2448x2048
Sensor Pixel Size	7.4 x 7.4µm	4.65 x 4.65µm	4.65 x 4.65µm	4.4 x 4.4µm	3.75 x 3.75 µm	3.45 x 3.45 µm
A/D Converter	Analog Devices AD9949A 12-bit analog-to-digital converter					
Video Data Output	8, 16 and 24-bit digital data (see *Supported Data Formats*)					
Resolutions and FPS	See Section 4.2					
Partial Image Modes	Pixel binning and region of interest modes available via Format_7					
Interfaces	9-pin IEEE-1394b for camera control and video data transmission 4 general-purpose digital input/output (GPIO) pins.					
Power Requirements	Voltage: 8-30V. Power: less than 2.5W					
Gain	Automatic/Manual/One-Push Gain modes					
	0dB to 24dB					
Shutter	Automatic/Manual/One-Push Shutter modes					
	0.01ms to 66.63ms @ 15 FPS					
	Extended shutter modes for exposure times longer than 5 seconds					
Gamma	0.50 to 4.00					
Trigger Modes	DCAM v1.31 Trigger Modes 0, 1, 3, 4, 5, 14 and 15.[1]					
Signal To Noise Ratio	60 dB	60 dB	59 dB	60 dB	59 dB	58 dB
Read Noise	56 e-	61 e-	77 e-	10.5 e-	129 e-	127 e-
Full Well Depth	17000 e-	13000 e-	10278 e-	11500 e-	5200 e-	4100 e-
Dark Current	240 e-/s	51 e-/s	56 e-/s	57 e-/s	71 e-/s	39 e-/s
Dark Noise	14 e-/s	5 e-/s	3.9 e-/s	4.8 e-/s	6.0 e-/s	3.1 e-/s
Dimensions	29mm x 29mm x 30mm (without optics)					
Mass	58 grams (without optics)					
Lens Mount	C-mount					
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° to 45°C					
Storage Temperature	-30° to 60°C					
Warranty	Two years					
Operating Relative Humidity	20 to 80% (no condensation)					
Storage Relative Humidity	20 to 95% (no condensation)					

[1] Trigger modes 4 and 5 are supported only in 03S2 and 08S2 models.

1.3.1. Spectral Response

For the spectral response of each *Flea2* model, refer to the ***Spectral Response Curves*** section of the Appendix.

> *All **color models** 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**.*

1.3.2. Analog-to-Digital Converter

The *Flea2* incorporates an Analog Devices AD9949AKCPZ 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 www.analog.com.

Resolution	12-bit, 36MHz
Pixel Gain Amplifier	0dB to 18dB
Variable Gain Amplifier	6dB to 42dB 10-bit
Black Level Clamp	0 LSB to 255 LSB

The 12-bit conversion process produces 4,096 possible digital image values between 0 and 65,520, left aligned across a two byte data format. The four right-most bits are always zero.

1.4. System Requirements

- Processor
  Recommended – Intel Pentium® 4 2.0 GHz or compatible processor
  Minimum – Intel Pentium III 800 MHz or compatible processor
- Memory
  Recommended – 2GB
  Minimum - 256MB
- AGP video card with 64 MB video memory (128 MB recommended)
- Bus Configuration
  Recommended – PCI Express (PCI-e card not included) or 64-bit PCI slot
  Minimum – 32-bit standard PCI slot for the IEEE-1394 card
- Microsoft Windows XP Service Pack 1
- Microsoft Visual C++ 6.0 (to compile and run example code)

1.4.1. Laptop / Notebook Considerations

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 their Point Grey camera on the Macintosh OS/X or Linux operating systems should consult the following knowledge base articles:

Macintosh support: www.ptgrey.com/support/kb/index.asp?a=4&q=173
Linux support: www.ptgrey.com/support/kb/index.asp?a=4&q=17

1.5. Controlling the Camera

The *Flea2* can be controlled by the following types of applications:

1.5.1. FlyCap Demo Program

The FlyCap application is a generic streaming image viewer included with the FlyCapture® SDK that can be used to test many of the capabilities of your compatible PGR IEEE-1394 camera. It allows you to view a live video stream from the camera, save individual images or .avi movie clips, adjust the various video formats, frame rates, properties and settings of the camera, and access camera registers. It is an easy-to-use program that can be used to test many of the capabilities of your PGR IEEE-1394 camera system. Consult the *PGR FlyCapture User Manual* for more information.

1.5.2. Custom Applications Built with the FlyCapture API

PGR FlyCapture includes a full Application Programming Interface that allows customers to create custom applications to control Point Grey Imaging Products. The SDK provides a number of sample programs and source code that is meant to help the advanced programmer get started using the FlyCapture API. Examples range from simple console programs that demonstrate the basic functionality of the API, such as PGRFlyCaptureTest, to more complex examples such as the MFC application FlyCap.

1.5.3. Third-Party Software Applications

The following knowledge base article provides information on Point Grey IEEE-1394 camera compatibility with third-party software development kits, applications, camera drivers, and integrated development environments (IDEs):

KB Article 152: www.ptgrey.com/support/kb/index.asp?a=4&q=152

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*, included with the FlyCapture SDK and 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.
- Users who have purchased a bare board camera should take the following additional protective measures:
  - Either handle bare handed or use non-chargeable gloves, clothes or material. Also, use conductive shoes.
  - Install a conductive mat on the floor or working table to prevent the generation of static electricity.
- 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.
- To clean the imaging surface of your CCD, follow the steps outlined in www.ptgrey.com/support/kb/index.asp?a=4&q=66.
- Our cameras are designed for an office environment or laboratory use. Extended exposure to bright sunlight, rain, dusty environments, etc. may cause problems with the electronics and the optics of the system.
- Avoid excessive shaking, dropping or any kind of mishandling of the device.

1.7.1. Case Temperature and Heat Dissipation

The *Flea2* is an ultra-compact camera. As a result of packing the *Flea2* electronics into a small space, the outer case of the camera can become very warm to the touch when running in some high data rate video modes. The case can reach temperatures up to 45° Celsius under normal operating conditions. This is expected behaviour and will not damage the camera electronics.

If reducing heat is a concern, users can use a cooling fan to set up a positive air flow around the camera, taking into consideration the following precautions:

- Mount the camera on a heat sink, such as a camera mounting bracket, made out of a heat-conductive material like aluminum.
- Make sure the flow of heat from the camera case to the bracket is not blocked by a non-conductive material like plastic.
- Make sure the camera has enough open space around it to facilitate the free flow of air.

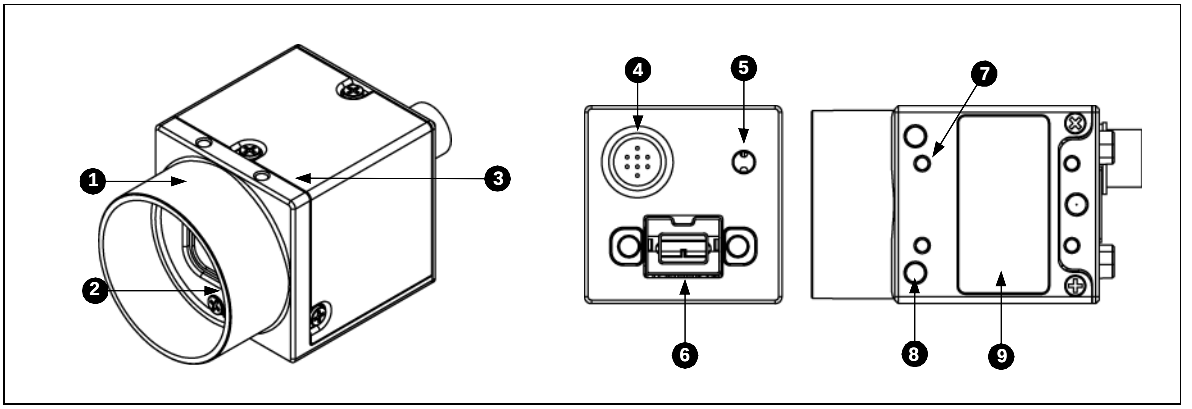
1.8. Camera Accessories

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. Physical Description



1. **Lens holder (C-mount)**
   Attach any C-mount lens or other optical equipment. Consult the section *Lens Setup and Compatibility* for full details.

2. **Glass / IR filter system**
   Refer to the *Dust Protection* and the *Infrared Cut-Off Filters* section for more information.

3. **M2x2 mounting holes**
   Refer to the *Mounting* section for full details.

4. **General purpose I/O connector**
   The 8-pin GPIO connector is used for external triggering, strobe output or digital I/O. Refer to the *General Purpose Input/Output* section for more information.

5. **Status LED**
   This light indicates the current state of the *Flea2* operation. Refer to the section *Status Indicator LED*.

6. **IEEE-1394b connector**
   The camera uses a standard 9-pin 1394b connector. M3 screw holes are located on either side of the connector for secure connection to the 9-pin locking 1394b cable. See the *IEEE-1394 Connector* section for full connector details.

7. **M2x2 mounting holes**

8. **M3x2.5 mounting holes**
   Refer to the *Mounting* section for full details.

9. **Camera label**
   Contains camera information such as model name, serial number and required compliance information.

2.2. Camera Dimensions

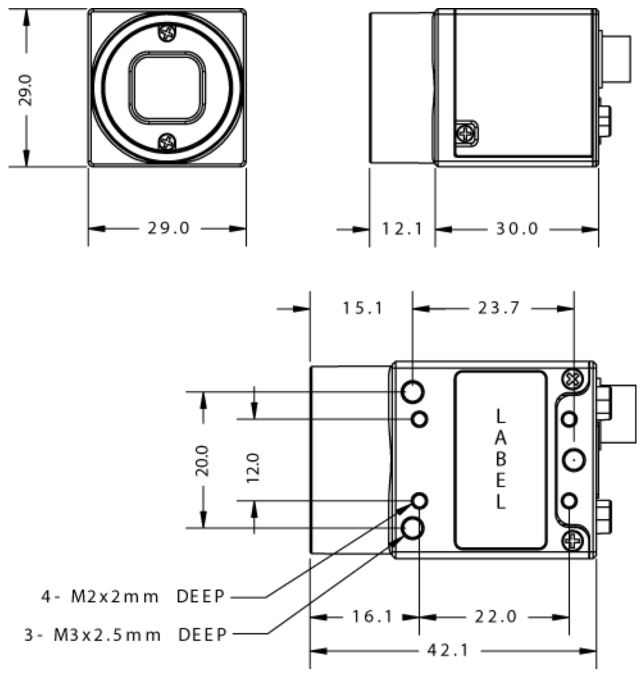


Figure 1: Dimensional drawing

2.3. Lens Setup and Compatibility

The lens holder is compatible with C-mount lenses. Lenses are not included with individual cameras. The figure below shows the dimensions of the lens mount.

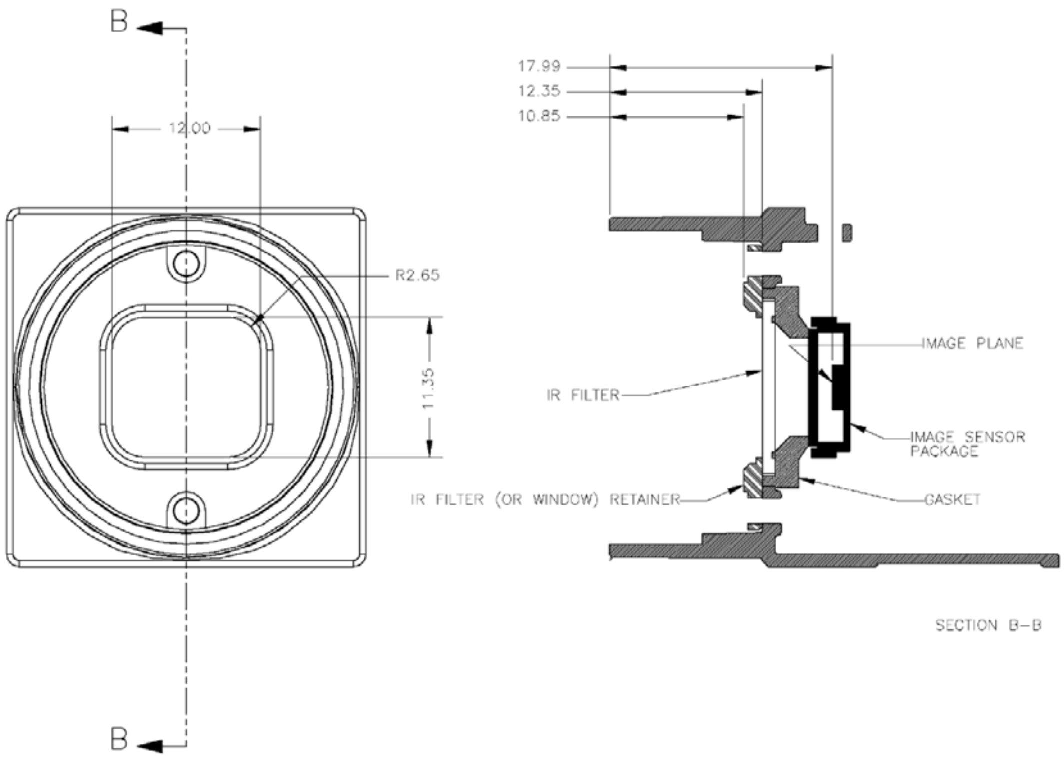


Figure 2: Lens Mount Dimensional Drawing

Although the C-mount lens specification for flange back distance (BFD) is 17.52 mm, these distances are offset due to the presence of both a 1 mm infrared cutoff (IRC) filter and a 0.5 mm sensor package window. These two pieces of glass fit between the lens and the sensor image plane. The IRC filter is installed on color cameras. In monochrome cameras, it is a transparent piece of glass. The sensor package window is installed by the sensor manufacturer. Both components cause refraction, which requires some offset in flange back distance to correct. The resulting BFD is 17.99 mm.

Correct focus cannot be achieved when using a CS-mount lens on a C-mount camera.

For more information about the infra-red cutoff (IRC) filter, see Section 2.6 Infrared Cut-Off Filters.

2.4. Dust Protection

> *Cameras are sealed when they are shipped. To avoid contamination, seals should not be broken until cameras are ready for assembly at customer's site.*
>
> *Do not remove the protective glass. Doing so can void the* Hardware Warranty *described at the beginning of this reference manual.*

The case is designed to prevent dust from falling directly onto the CCD's protective glass surface. This is achieved by placing a piece of clear glass (monochrome camera models) or IR cut-off filter (color models) that sits above the surface of the CCD's glass. A removable plastic retainer keeps this glass/filter system in place. By increasing the distance between the imaging surface and the location of the potential dust particles, the likelihood of interference from the dust (assuming non-collimated light) and the possibility of damage to the sensor during cleaning is reduced.

2.5. Mounting

2.5.1. Using the Case

The case is equipped with the following mounting holes:

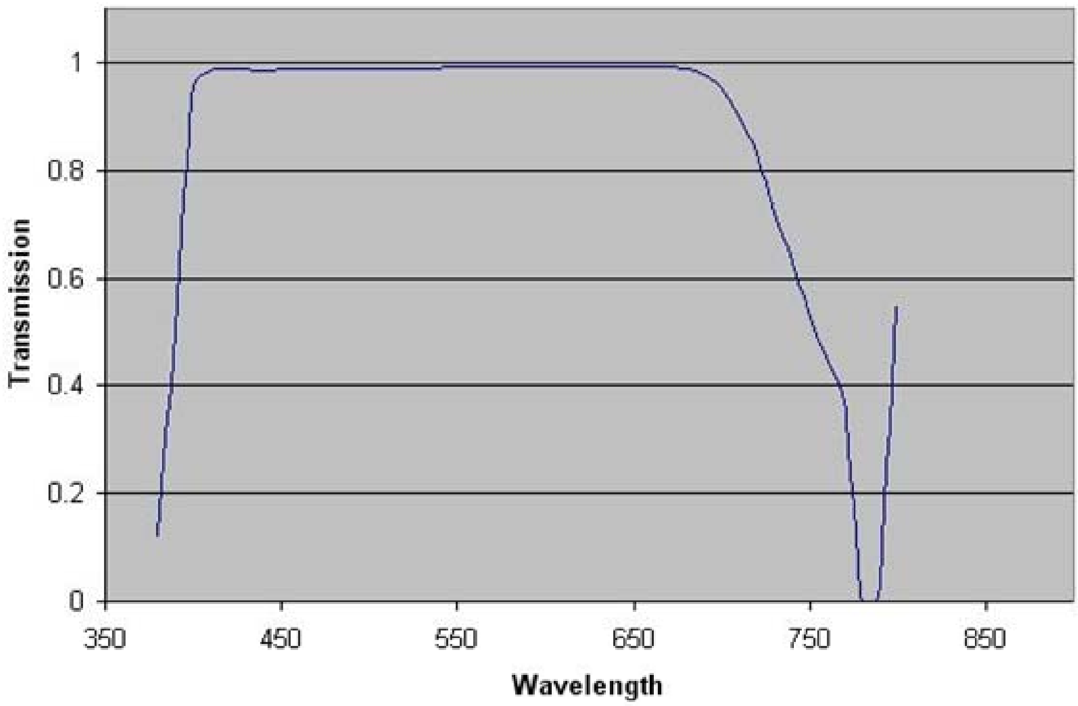
- Two (2) M2x2mm mounting holes on the top of the case
- Three (3) M3x2.5mm mounting holes on the bottom of the case
- Four (4) M2x2mm mounting holes on the bottom of the case that can be used to attach the camera directly to a custom mount or to the *Flea2* tripod mounting bracket

2.5.2. Using the Tripod Mounting Bracket

The *Flea2* tripod mounting bracket comes with the Development Kit, or can be purchased separately by contacting sales@ptgrey.com. The bracket is equipped with two (2) M3 and one (1) M2 mounting holes.

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.



In monochrome models, the IR filter is replaced with a transparent piece of glass.

The following are the properties of the IR filter/protective glass[1]:

Type	Reflective
Material	Schott D 263 T or BK7 equivalent for coating filters
Physical Filter Size	14 mm x 14 mm
Glass Thickness	1.0 mm
Dimensional Tolerance	+/-0.1 mm`
Coating Filters	Scott D 263 T

[1] These properties apply to all imaging cameras except GRAS 14S5.

Related Knowledge Base Articles

ID	Title	URL
98	Understanding flange back distance on C-mount and CS-mount cameras	www.ptgrey.com/support/kb/index.asp?a=4&q=98

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 Flea2 *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 (included with* Flea2 *Development Kits).*

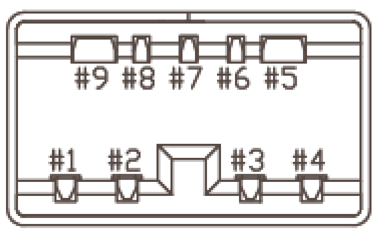


Figure 3: IEEE-1394b connector pin configuration

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 1: IEEE-1394b connector pin configuration

3.2. Cables

The maximum 1394 cable length between any 1394 node (e.g. camera to PCI card, PCI card to hub, etc.) is 4.5m, as specified by the IEEE-1394 standard. Standard, shielded twisted pair copper cables must be used. Consult the following knowledge base article for information on how to extend the physical distance between the camera and the controlling host system:

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

3.3. Host Adapter Card

All camera KITs (e.g. part numbers ending with "KIT") come with a 3-port IEEE-1394 PCI host adapter card. 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 6-pin 1394 connector (9-pin for 1394b cameras) connects to a standard IEEE-1394 (FireWire) 6-pin (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. 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 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

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 *Flea2* has an 8-pin GPIO connector on the back 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	Input / Output (default Trigger_Src)
	2	IO1	Input / Output
	3	IO2	Input / Output / RS232 Transmit (TX)
	4	IO3	Input / Output / RS232 Receive (RX)
	5	GND	Ground pin for all pins
	6	GND	Ground pin for all pins
	7	V_{EXT}	Allows the camera to be powered externally
	8	+3.3V	Power external circuitry up to 150mA

Table 2: FL2 GPIO pin assignments

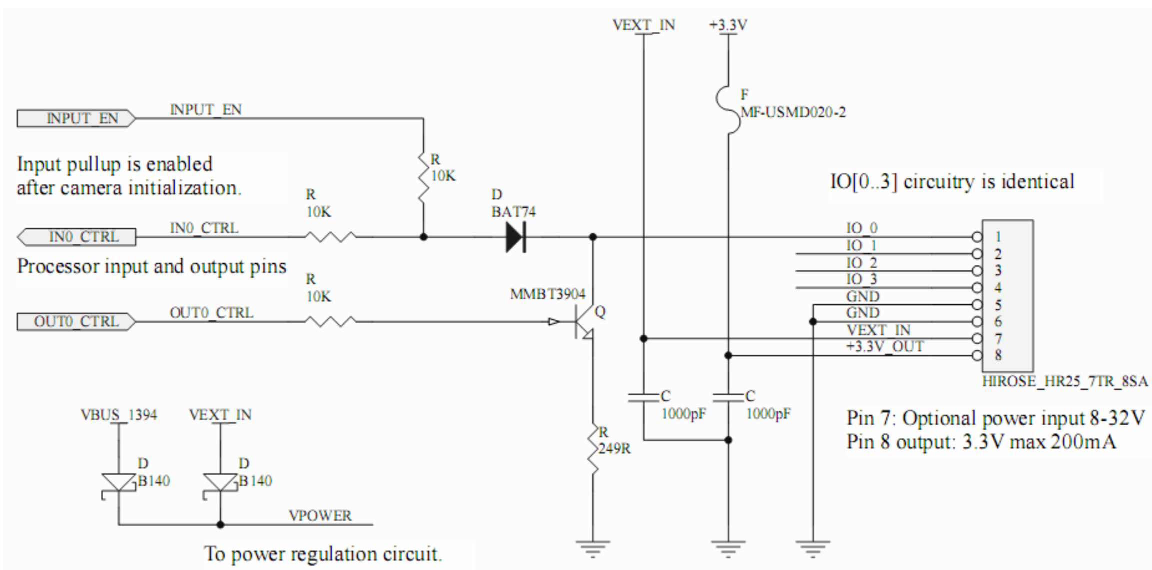


Figure 4: FL2 GPIO schematic

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

Table 3: FL2G 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 differences in GPIO functionality between the FL2 and FL2G models, download Technical Application Note TAN2008004. For more information on using the RS232 serial port, download Technical Application Note TAN2004001. Downloads are available from www.ptgrey.com/support/downloads/.

3.5.1. GPIO Electrical Characteristics

The *Flea2* 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
Off	Not receiving power
Steady on	Receiving power and successful camera initialization
Steady on and very bright	Acquiring / transmitting images
Flashing bright, then brighter	Camera registers being accessed (no image acquisition)
Steady flashing on and off	Indicates possible camera problem
Slow flashing on and off	Indicates possible camera problem

Table 4: Status indicator LED descriptions

4 Camera Operations and Features

The *Flea2* line of IEEE-1394 cameras complies with the *IIDC 1394-based Digital Camera (DCAM) Specification Version v1.31*.

To determine the specific DCAM v1.31 features implemented in a particular *Flea2* model, 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

You can query the registers described in these sections to identify whether specific features have been implemented. For a complete description of the Camera Control Command Registers implemented on the *Flea2*, please refer to the *PGR IEEE-1394 Digital Camera Register Reference*, included with the PGR FlyCapture SDK and 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 *Flea2*. Descriptions of some of the following properties and how they are implemented can be found in this *Technical Reference*. Refer to the *PGR IEEE-1394 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 *Flea2* FL2-03S2C running at 15 FPS, and can change depending on the camera resolution and frame rate:

- Shutter / Extended Shutter: maximum values increase as frame rate decreases
- Pan / Tilt: maximum values increase with smaller non-Format_7 resolutions
- Frame Rate: range changes according to the current frame rate

Properties marked with a ‘(COL)’ *apply to color models only and are not implemented on cameras using a monochrome sensor.*

Property	Units	Min	Max	Auto	On/Off	One Push	Absolute Mode
Brightness	%	0	6.23	N	N	N	Y
Auto Exposure	EV	-7.58	2.41	Y	Y	Y	Y
Sharpness		0	4095	Y	Y	N	N
White Balance		1	1023	Y	Y	Y	N
Hue (COL)	deg	-180	179.91	Y	N	N	Y
Saturation (COL)	%	0	399.9	Y	Y	N	Y
Gamma		0.5	4	Y	N	N	Y
Pan		0	8	Y	Y	N	N
Tilt		0	8	Y	Y	N	N
Shutter	ms	0	66.64	N	Y	Y	Y
Gain	dB	0	24.04	N	Y	Y	Y
Trigger Delay	s	0	65	Y	N	N	Y
Frame Rate	fps	0.13	15.68	Y	Y	N	Y
Extended Shutter	ms	0.01	63312.04				

4.2. Standard Data Formats, Modes and Frame Rates

This section lists the different video formats, modes and frame rates that are supported by the *Flea2*. Refer to the *Customizable Formats and Modes* for a list of supported partial image (Format_7) modes. These standard modes are controlled using the following IIDC registers:

- CURRENT_VIDEO_FORMAT register 0x608
- CURRENT_VIDEO_MODE register 0x604
- CURRENT_FRAME_RATE register 0x600

Images acquired by color cameras using Y8 or Y16 modes (or Format_7 Mono8 / Mono16 modes) are converted to greyscale (monochrome) on-board the camera. To access the raw Bayer data to apply different color conversion algorithms or one of the FlyCapture library algorithms, refer to the Color and Greyscale Conversion section of this manual.

Monochrome models in Y16 mode report the presence of the Sharpness feature in the Feature_HI_Inq register 404h and the Sharpness register 808h. However, the feature is off and cannot be turned on.

Some smaller format / mode combinations (e.g. 320x240 on an FL2-08S2, or 160x120 on an FL2-03S2) currently run at 5/6th of the frame rate reported in the following table (e.g. 25 FPS instead of 30 FPS).

Models: 🔵 03S2C ⚫ 03S2M 🟢 08S2C 🟠 08S2M

Modes	1.875fps	3.75fps	7.5fps	15fps	30fps	60fps
160x120 YUV444			🔵🟢	🔵🟢	🔵🟢	🔵
320x240 YUV422	🔵🟢	🔵🟢	🔵🟢	🔵🟢	🔵🟢	🔵
640x480 YUV411	🔵🟢	🔵🟢	🔵🟢	🔵🟢	🔵🟢	🔵
640x480 YUV422	🔵🟢	🔵🟢	🔵🟢	🔵🟢	🔵🟢	
640x480 RGB	🔵🟢	🔵🟢	🔵🟢	🔵🟢	🔵🟢	
640x480 Y8	🔵🟢⚫🟠	🔵🟢⚫🟠	🔵🟢⚫🟠	🔵🟢⚫🟠	🔵🟢⚫🟠	🔵⚫
640x480 Y16	🔵🟢⚫🟠	🔵🟢⚫🟠	🔵🟢⚫🟠	🔵🟢⚫🟠	🔵🟢⚫🟠	🔵⚫
800x600 YUV422		🟢	🟢	🟢	🟢	
800x600 RGB			🟢	🟢	🟢	
800x600 Y16		🟢	🟢	🟢	🟢	
800x600 Y8			🟢	🟢	🟢	
1024x768 YUV422	🟢	🟢	🟢	🟢	🟢	
1024x768 RGB	🟢	🟢	🟢	🟢		
1024x768 Y16	🟢🟠	🟢🟠	🟢🟠	🟢🟠	🟢🟠	

1024x768 Y8	●●	●●	●●	●●	●●	

Table 5: Supported video formats, modes and frame rates (FL2-03S2 and FL2-08S2)

Models: ● 14S3C ● 14S3M ● 20S4C ● 20S4M

Modes	1.875fps	3.75fps	7.5fps	15fps	30fps	60fps
320x240 YUV422	14S3C	14S3C	14S3C	14S3C	14S3C	
640x480 YUV411	14S3C	14S3C	14S3C	14S3C	14S3C	
640x480 YUV422	14S3C	14S3C	14S3C	14S3C	14S3C	
640x480 RGB	14S3C	14S3C	14S3C	14S3C	14S3C	
640x480 Y8	14S3C, 14S3M	14S3C, 14S3M	14S3C, 14S3M	14S3C, 14S3M	14S3C, 14S3M	
640x480 Y16	14S3C, 14S3M	14S3C, 14S3M	14S3C, 14S3M	14S3C, 14S3M	14S3C, 14S3M	
800x600 YUV422		20S4C, 20S4M	20S4C, 20S4M	20S4C, 20S4M		
800x600 RGB			20S4C, 20S4M	20S4C, 20S4M		
800x600 Y16		20S4C, 20S4M	20S4C, 20S4M	20S4C, 20S4M		
800x600 Y8			20S4C, 20S4M	20S4C, 20S4M		
1280x960 YUV422	14S3C, 20S4C	14S3C, 20S4C	14S3C, 20S4C	14S3C, 20S4C		
1280x960 RGB	14S3C, 20S4C	14S3C, 20S4C	14S3C, 20S4C	14S3C, 20S4C		
1280x960 Y16	14S3C, 14S3M, 20S4C, 20S4M	14S3C, 14S3M, 20S4C, 20S4M	14S3C, 14S3M, 20S4C, 20S4M	14S3C, 14S3M, 20S4C, 20S4M		
1280x960 Y8	14S3C, 14S3M, 20S4C, 20S4M	14S3C, 14S3M, 20S4C, 20S4M	14S3C, 14S3M, 20S4C, 20S4M	14S3C, 14S3M, 20S4C, 20S4M		
1600x1200 YUV422	20S4C	20S4C	20S4C	20S4C		
1600x1200 RGB	20S4C	20S4C	20S4C			
1600x1200 Y16	20S4C, 20S4M	20S4C, 20S4M	20S4C, 20S4M	20S4C		
1600x1200 Y8	20S4C, 20S4M	20S4C, 20S4M	20S4C, 20S4M	20S4C		

Table 6: Supported video formats, modes and frame rates (FL2-14S3 and FL2-20S4)

Models: ● 13S2C ● 13S2M ● 50S5C ● 50S5M

Modes	1.875fps	3.75fps	7.5fps	15fps	30fps	60fps
320x240 YUV422	13S2C	13S2C	13S2C	13S2C	13S2C	
640x480 YUV411	13S2C	13S2C	13S2C	13S2C	13S2C	
640x480 YUV422	13S2C	13S2C	13S2C	13S2C	13S2C	
640x480 RGB	13S2C	13S2C	13S2C	13S2C	13S2C	
640x480 Y8	13S2C, 13S2M	13S2C, 13S2M	13S2C, 13S2M	13S2C, 13S2M	13S2C, 13S2M	
640x480 Y16	13S2C, 13S2M	13S2C, 13S2M	13S2C, 13S2M	13S2C, 13S2M	13S2C, 13S2M	
800x600 YUV422		13S2C	13S2C	13S2C	13S2C	
800x600 RGB			13S2C	13S2C	13S2C	
800x600 Y16		13S2C	13S2C	13S2C	13S2C	
800x600 Y8			13S2C, 13S2M	13S2C, 13S2M	13S2C, 13S2M	
1024x768 Y8	13S2C, 13S2M, 50S5M, 50S5C	13S2C, 13S2M, 50S5M, 50S5C	13S2C, 13S2M, 50S5M, 50S5C	13S2C, 13S2M, 50S5M, 50S5C	13S2C, 13S2M	
1024x768 Y16	13S2C, 13S2M, 50S5M, 50S5C	13S2C, 13S2M, 50S5M, 50S5C	13S2C, 13S2M, 50S5M, 50S5C	13S2C, 13S2M, 50S5M, 50S5C	13S2C, 13S2M	
1024x768 RGB	13S2C, 50S5C	13S2C, 50S5C	13S2C, 50S5C	13S2C, 50S5C		
1024x768 YUV422	13S2C, 50S5C	13S2C, 50S5C	13S2C, 50S5C	13S2C, 50S5C		
1280x960 YUV422	13S2C	13S2C	13S2C	13S2C		
1280x960 RGB	13S2C	13S2C	13S2C	13S2C		
1280x960 Y8	13S2C, 13S2M	13S2C, 13S2M	13S2C, 13S2M	13S2C, 13S2M	13S2C, 13S2M	
1280x960 Y16	13S2C, 13S2M	13S2C, 13S2M	13S2C, 13S2M	13S2C, 13S2M	13S2M	
1600x1200 YUV422	50S5C	50S5C	50S5C			
1600x1200 RGB	50S5C	50S5C	50S5C			
1600x1200 Y8	50S5M, 50S5C	50S5M, 50S5C	50S5M, 50S5C			
1600x1200 Y16	50S5M, 50S5C	50S5M, 50S5C	50S5M, 50S5C			

Table 7: Supported video formats, modes and frame rates (FL2G-13S2 and FL2G-50S5)

4.3. Frame Rates and Camera Bandwidth

> *This section is recommended for advanced users only, and is not meant to address all possible applications of the* Flea2 *camera.*

4.3.1. 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 TI chipset can support at most 4 simultaneous DMA channels (or contexts). There are no known 1394b chipsets that allow more than 4 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.

4.3.2. Exceeding Bandwidth Limitations Using Format_7

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. An interactive bandwidth calculator is available in Knowledge Base Article 22. It can be used to calculate approximate bandwidth requirements for various DCAM modes. For additional information, see Knowledge Base Article 256.

4.3.3. 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 three 1024x768 *Flea2s* that are in 16-bit mode, you would calculate:

Frames_per_second = (80MB/s / (1024*768*2bytes/pixel)) / 3
= (80MB/s / 1.5MB/frame) / 3
= 53.33 FPS / 3
= 17.8 FPS

The calculation above is only a rough estimate. The DCAM standard defines a specific number of bytes per packet (BPP) for every non-Format_7 video format/mode/frame rate combination. This number is generally higher than the minimum bandwidth that might be expected. In order to accurately determine whether or not there is enough bandwidth available for a given scenario, these numbers must be used. The BPP can be derived using the *Isochronous Bandwidth Requirements* section of the *PGR IEEE-1394 Digital Camera Register Reference*.

For example, a single *Flea2* in 640x480 RGB mode running at 15 FPS is sending 640 pixels per packet. Each pixel consists of 24 bits, or 3 bytes, of data. Therefore, the camera is sending 640*3 = 1920Bpp of data. The maximum bandwidth of the 1394b bus as discussed above is 8192Bpp, so it would be possible for 8192/1920 = 4 (rounded down) *Flea2*'s to run in 640x480 RGB mode at 15 FPS on the same 1394b bus.

4.4. Customizable Data Formats and Modes

The table below outlines the Format_7 custom image modes that are supported by the *Flea2*. The implementation of these modes and the frame rates that are possible are not specified by the DCAM, and are subject to change across firmware versions.

Mode_0, Mode_1, Mode_2 and Mode_3 are region of interest (sub-window) modes that allow the user to only transmit a selected area of the image. Mode_1 and Mode_2 are also pixel binning (subsampling) modes. Color binning is supported in the 14S3C and 20S4C models. Refer to the *Pixel Binning and Region of Interest Modes* section for information on mode implementation.

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), unless the change is illegal (e.g. moving the ROI outside the imaging area) or would affect the isochronous packet size. Changing the size of the image or the pixel encoding format does require the stop/start procedure. Ignoring the time required to do this in software (tearing down, then reallocating, image buffers, write times to the camera, etc.), the maximum amount of time required for the stop/start procedure is slightly more than one frame time.

The sizes and frame rates supported by monochrome (BW) models are identical to the color models specified below, with the exception that only Mono8 and Mono16 are supported. Images acquired by color cameras using Mono8 or Mono16 modes are converted to greyscale (monochrome) on-board the camera. Users interested in accessing the raw Bayer data to apply their own color conversion algorithm or one of the FlyCapture library algorithms should refer to the Color and Greyscale Conversion *section of this manual.*

When operating in Format_7 mode, the Feature_Lo_Inq register 408h and the Pan and Tilt registers 884h and 888h report the presence of the Pan and Tilt features. However, these features are off and cannot be turned on.

FL2-03S2C

Mode	Pixel Format	Max Size (HxV)	Unit Size (H,V)	Min BPP (Max Size)	Max BPP (Max Size)	Max FPS
0	Mono8	648x488	8,2	40	3440	83
0	Mono16	648x488	8,2	80	6880	83
0	Raw8	648x488	8,2	40	3440	83
0	Raw16	648x488	8,2	80	6880	83
0	YUV411	648x488	8,2	60	5160	83
0	YUV422	648x488	8,2	80	6880	83
0	YUV444	648x488	8,2	120	8160	65
0	RGB8	648x488	8,2	120	8160	65
1	Mono8	324x244	4,2	20	1560	143
1	Mono16	324x244	4,2	40	3120	143
1	YUV411	324x244	4,2	16	1296	83
1	YUV422	324x244	4,2	20	1720	83
1	YUV444	324x244	4,2	32	2592	83
1	RGB8	324x244	4,2	32	2592	83
2	Mono8	648x244	8,2	20	1720	83
2	Mono16	648x244	8,2	40	3440	83
2	YUV411	648x244	8,2	32	2592	83
2	YUV422	648x244	8,2	40	3440	83
2	YUV444	648x244	8,2	60	5160	83
2	RGB8	648x244	8,2	60	5160	83

Table 8: Supported partial image (Format 7) video formats and modes for FL2-03S2C

FL2-08S2C

Mode	Pixel Format	Max Size (HxV)	Unit Size (H,V)	Min BPP (Max Size)	Max BPP (Max Size)	Max FPS
0	Mono8	1032x776	8,2	196	3136	31
0	Mono16	1032x776	8,2	388	6596	32
0	Raw8	1032x776	8,2	196	3136	31
0	Raw16	1032x776	8,2	388	6596	32
0	YUV411	1032x776	8,2	292	4672	30
0	YUV422	1032x776	8,2	388	6596	32
0	YUV444	1032x776	8,2	584	8176	27
0	RGB8	1032x776	8,2	584	8176	27
1	Mono8	516x388	4,2	100	1400	53
1	Mono16	516x388	4,2	196	2744	52
1	YUV411	516x388	4,2	76	1216	32
1	YUV422	516x388	4,2	100	1600	31
1	YUV444	516x388	4,2	148	2368	31
1	RGB8	516x388	4,2	148	2368	31
2	Mono8	1032x388	8,2	100	1600	31
2	Mono16	1032x388	8,2	196	3136	31
2	YUV411	1032x388	8,2	148	2368	31
2	YUV422	1032x388	8,2	196	3136	31
2	YUV444	1032x388	8,2	292	4672	30
2	RGB8	1032x388	8,2	292	4672	30

Table 9: Supported partial image (Format 7) video formats and modes for FL2-08S2C

FL2-14S3C

Mode	Pixel Format	Max Size (HxV)	Unit Size (H,V)	Min BPP (Max Size)	Max BPP (Max Size)	Max FPS
0	Mono8	1392x1032	8,2	264	2904	16
0	Mono16	1392x1032	8,2	524	5764	16
0	Raw8	1392x1032	8,2	264	2904	16
0	Raw16	1392x1032	8,2	524	5764	16
0	YUV411	1392x1032	8,2	392	4312	16
0	YUV422	1392x1032	8,2	524	5764	16
0	YUV444	1392x1032	8,2	784	7840	14
0	RGB8	1392x1032	8,2	784	7840	14
1	Mono8	696x516	4,2	132	1452	31
1	Mono16	696x516	4,2	264	2904	31
1	YUV411	696x516	4,2	196	2156	31
1	YUV422	696x516	4,2	264	2904	31
1	YUV444	696x516	4,2	396	4356	31
1	RGB8	696x516	4,2	396	4356	31
2	Mono8	1392x516	8,2	264	2904	31
2	Mono16	1392x516	8,2	524	5764	31
2	Raw8	1392x516	8,2	264	2904	31
2	Raw16	1392x516	8,2	524	5764	31
2	YUV411	1392x516	8,2	392	4312	31
2	YUV422	1392x516	8,2	524	5764	31
2	YUV444	1392x516	8,2	784	7840	28
2	RGB8	1392x516	8,2	784	7840	28

Table 10: Supported partial image (Format 7) video formats and modes for FL2-14S3C

FL2-20S4C

Mode	Pixel Format	Max Size (HxV)	Unit Size (H,V)	Min BPP (Max Size)	Max BPP (Max Size)	Max FPS
0	Mono8	1624x1224	8,2	308	3696	15
0	Mono16	1624x1224	8,2	612	7344	14
0	Raw8	1624x1224	8,2	308	3696	15
0	Raw16	1624x1224	8,2	612	7344	14
0	YUV411	1624x1224	8,2	460	5520	15
0	YUV422	1624x1224	8,2	612	7344	14
0	YUV444	1624x1224	8,2	916	7328	10
0	RGB8	1624x1224	8,2	916	7328	10
1	Mono8	812x612	4,2	156	1560	24
1	Mono16	812x612	4,2	308	3388	26
1	YUV411	812x612	4,2	232	2320	24
1	YUV422	812x612	4,2	308	3388	26
1	YUV444	812x612	4,2	460	5060	26
1	RGB8	812x612	4,2	460	5060	26
2	Mono8	1624x612	8,2	308	3388	26
2	Mono16	1624x612	8,2	612	6732	26
2	Raw8	1624x612	8,2	308	3388	26
2	Raw16	1624x612	8,2	612	6732	26
2	YUV411	1624x612	8,2	460	5060	26
2	YUV422	1624x612	8,2	612	6732	26
2	YUV444	1624x612	8,2	916	7328	19
2	RGB8	1624x612	8,2	916	7328	19

Table 11: Supported partial image (Format 7) video formats and modes for FL2-20S4C

FL2G-13S2C

Mode	Pixel Format	Max Size (HxV)	Unit Size (H,V)	Min BPP (Max Size)	Max BPP (Max Size)	Max FPS
0	Mono8	1288x964	8,2	4	4840	31
0	Mono16	1288x964	8,2	8	9680	31
0	Raw8	1288x964	8,2	4	4840	31
0	Raw16	1288x964	8,2	8	9680	31
0	YUV411	1288x964	8,2	8	7256	31
0	YUV422	1288x964	8,2	8	9680	31
0	YUV444	1288x964	8,2	16	9792	21
0	RGB8	1288x964	8,2	16	9792	21
1	Mono8	644x482	4,2	4	2288	57
1	Mono16	644x482	4,2	4	4580	57
1	YUV411	644x482	4,2	4	1812	31
1	YUV422	644x482	4,2	4	2420	31
1	YUV444	644x482	4,2	4	3628	31
1	RGB8	644x482	4,2	4	3628	31
2	Mono8	1288x482	8,2	4	2420	31
2	Mono16	1288x482	8,2	4	4840	31
2	YUV411	1288x482	8,2	4	3628	31
2	YUV422	1288x482	8,2	4	4840	31
2	YUV444	1288x482	8,2	8	7256	31
2	RGB8	1288x482	8,2	8	7256	31

3	Mono8	644x964	4,2	4	2420	31
3	Mono16	644x964	4,2	4	4840	31
3	Raw8	644x964	4,2	4	2420	31
3	Raw16	644x964	4,2	4	4840	31
3	YUV411	644x964	4,2	4	3628	31
3	YUV422	644x964	4,2	4	4840	31
3	YUV444	644x964	4,2	8	7256	31
3	RGB8	644x964	4,2	8	7256	31

Table 12: Supported partial image (Format 7) video formats and modes for FL2G-13S2C

FL2G-50S5C

Mode	Pixel Format	Max Size (HxV)	Unit Size (H,V)	Min BPP (Max Size)	Max BPP (Max Size)	Max FPS
0	Mono8	2448x2048	8,2	4	3896	7.8
0	Mono16	2448x2048	8,2	4	3896	7.8
0	Raw8	2448x2048	8,2	4	3896	7.8
0	Raw16	2448x2048	8,2	4	3896	7.8
0	YUV411	2448x2048	8,2	4	3896	7.8
0	YUV422	2448x2048	8,2	4	3896	7.8
0	YUV444	2448x2048	8,2	4	3896	5.2
0	RGB8	2448x2048	8,2	4	3896	5.2
1	Mono8	1224x1024	4,2	4	1676	13
1	Mono16	1224x1024	4,2	4	3356	13
1	Raw8	1224x1024	4,2	4	1676	13
1	Raw16	1224x1024	4,2	4	3356	13
1	YUV411	1224x1024	4,2	4	2516	13
1	YUV422	1224x1024	4,2	4	3356	13
1	YUV444	1224x1024	4,2	4	5032	13
1	RGB8	1224x1024	4,2	4	5032	13
2	Mono8	2448x1024	8,2	4	3356	13
2	Mono16	2448x1024	8,2	4	6712	13
2	Raw8	2448x1024	8,2	4	3356	13
2	Raw16	2448x1024	8,2	4	6712	13
2	YUV411	2448x1024	8,2	4	5032	13
2	YUV422	2448x1024	8,2	4	6712	13
2	YUV444	2448x1024	8,2	8	9792	10
2	RGB8	2448x1024	8,2	8	9792	10
3	Mono8	1224x2048	4,2	4	1948	7.8
3	Mono16	1224x2048	4,2	4	3896	7.8
3	Raw8	1224x2048	4,2	4	1948	7.8
3	Raw16	1224x2048	4,2	4	3896	7.8
3	YUV411	1224x2048	4,2	4	2920	7.8
3	YUV422	1224x2048	4,2	4	3896	7.8
3	YUV444	1224x2048	4,2	8	5840	7.8
3	RGB8	1224x2048	4,2	8	5840	7.8

Table 13: Supported partial image (Format 7) video formats and modes for FL2G-50S5C

4.4.1. Calculating Format_7 Frame Rates

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 an image size of 1032x776, pixel format of Mono16 (2 bytes per pixel), and 3072 bytes per packet, the calculation would be as follows:

FPS = 1 / ((1032*776*2 / 3072) * 0.000125)
FPS = 1 / (521 / 8000)
FPS = 15.34

4.5. Image Acquisition

4.5.1. Camera Power

The *Flea2* 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 unless the camera is in asynchronous trigger mode. 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.

4.5.2. Shutter

The *Flea2* supports automatic, manual and one-push control of the CCD shutter time. Refer to the *General Specifications* section for detailed information on supported shutter time ranges. 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 *PGR IEEE-1394 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 *Flea2* will continually expose and read image data off of the sensor under the following conditions:

1. The camera is powered up (see *Camera Power* above); **and**
2. The camera is not in asynchronous trigger mode. When in async trigger mode, the camera simply clears the sensor and does not read the data off the sensor.

It is important to note that the camera will continue exposing images even when isochronous data transfer is disabled and images are not being streamed to the PC. The camera continues exposing images even when ISO is off in order to keep things such as the auto exposure algorithm (if enabled) running. This is done to ensure that when a user starts requesting images (ISO turned on), the first image they receive will be properly exposed.

4.5.3. Gain

The *Flea2* 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 *PGR IEEE-1394 Digital Camera Register Reference*.

Increasing gain also increases image noise, which can affect image quality. To increase image intensity, try adjusting the lens aperature (iris) and shutter time first.

4.5.4. 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.

The auto exposure algorithm is only applied to the active region of interest, and not the entire array of active pixels.

4.5.5. Extended Shutter Times

The maximum shutter time for the *Flea2* can be extended beyond the normal shutter range by setting the *ON_OFF* bit [6] of the FRAME_RATE register 0x83C to zero (OFF). Once the FRAME_RATE is turned off, you should see the *Max_Value* of the ABS_VAL_SHUTTER register increase.

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* Max_Value *of the ABS_VAL_SHUTTER register to determine the maximum shutter.*

Model	Format and FPS	Min (ms)	Max (ms)	Notes
FL2-03S2M FL2-03S2C	640x480 Y8, 60 FPS	0.01	1978	
	640x480 Y8, 30 FPS	0.01	3957	
	640x480 Y8, 15 FPS	0.01	7914	
	640x480 Y8, 7.5 FPS	0.01	15828	
	640x480 Y8, 3.75 FPS	0.01	31656	
	640x480 Y8, 1.875 FPS	0.01	63312	
FL2-08S2M FL2-08S2C	1024x768 Y8, 30 FPS	0.01	2642	
	1024x768 Y8, 15 FPS	0.01	5285	
	1024x768 Y8, 7.5 FPS	0.01	10570	
	1024x768 Y8, 3.75 FPS	0.01	21141	
	1024x768 Y8, 1.875 FPS	0.01	42282	
FL2-14S3M FL2 -14S3C	640x480 Y8, 30 FPS	0.005	3964	
	640x480 Y8, 15 FPS	0.007	7928	
	640x480 Y8, 7.5 FPS	0.015	15856	
	640x480 Y8, 3.75 FPS	0.015	31712	
	640x480 Y8, 1.875 FPS	0.015	63424	
FL2-20S4M FL2-20S4C	800x600 Y8, 15 FPS	0.008	3172	
	800x600 Y8, 7.5 FPS	0.01	6341	
FL2G-13S2M FL2G-13S2C	640x480 Y8, 30 FPS	0.005	3435	
	640x480 Y8, 15 FPS	0.005	3435	
	640x480 Y8, 7.5 FPS	0.005	3435	
	640x480 Y8, 3.75 FPS	0.005	3435	
	640x480 Y8, 1.875 FPS	0.005	13087	
FL2G-50S5M FL2G-50S5C	1024x768 Y8, 15 FPS	0.01	4678	
	1024x768 Y8, 7.5 FPS	0.02	7197	
	1024x768 Y8, 3.75 FPS	0.02	7197	
	1024x768 Y8, 1.875 FPS	0.02	7197	

Table 14: Extended shutter minimum and maximum times

Related Knowledge Base Articles

ID	Title	URL
166	Extended shutter mode operation for DCAM 1.31-compliant PGR Imaging Products.	www.ptgrey.com/support/kb/index.asp?a=4&q=166

4.5.6. 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
112	Synchronizing PGR cameras across multiple PCs	www.ptgrey.com/support/kb/index.asp?a=4&q=112

4.5.7. Frame Rate Control

The current base frame rate is controlled using the CURRENT_FRAME_RATE register 0x600. The *Flea2* 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 *PGR IEEE-1394 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.

For example, users may wish to play an image stream back on a PAL-based system that displays at 25 FPS. To do this, set the CURRENT_FRAME_RATE to 30 FPS, set the *A_M_Mode* bit [7] of the FRAME_RATE register 0x83C to zero (manual), then adjust the value using the *Value* field or using the ABS_VAL_FRAME_RATE register (recommended).

4.5.8. Pixel Binning and Region of Interest Modes

The *Flea2* implements a number of DCAM Format_7 customizable video modes. These modes operate by selecting a specific region of interest (ROI) of the image or by configuring the camera to aggregate pixel values using processes called "pixel binning" and "subsampling." All Format_7 modes allow specifying an ROI. Mode_1 and Mode_2 also implement a combination of binning and subsampling. "Binning" refers to aggregation that takes place in an analog manner, directly on the sensor before readout. "Subsampling" refers to aggregation that takes place digitally on the FPGA, after readout. On color models of the FL2-14S3 and FL2-20S4, color data is maintained in pixel binning/subsampling modes, On other color models, the binning process destroys the Bayer tiling pattern, and only monochrome output is possible.

The figures below illustrate how binning works in general. 2x vertical binning aggregates adjacent vertical pixel values to form a single average pixel value; 2x horizontal binning works in the same manner, except adjacent horizontal pixel values are aggregated.

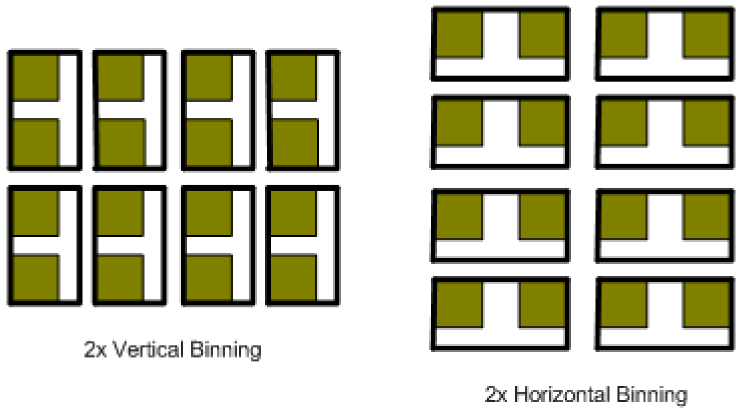


Figure 5: 2x Vertical and 2x Horizontal Binning

On Flea2 cameras in Format_7 Mode_1 or Mode_2, standard 2x vertical binning takes place on the sensor, while 2x horizontal subsampling takes place on the FPGA chip. To reduce the noise effects that may result from aggregating pixels, an adjustment in gain by 3dB is made during the vertical binning process. (On FL2-13S2 models, gain is adjusted by 6 dB.) During horizontal subsampling, pixel values are averaged after aggregation. The result is an increase in overall image intensity by a factor of approximately 1.4. On FL2-13S2 models, the increase is much closer to a factor of 1.

In addition to increased intensity, binning may allow for faster frame rates. For more information, see Section 4.4 Customizable Data Formats and Modes.

Related Knowledge Base Articles

ID	Title	URL
163	Understanding Format_7 region of interest and pixel binning modes	www.ptgrey.com/support/kb/index.asp?a=4&q=163

4.5.9. Y16 (16-bit Mono) Image Acquisition

The *Flea2* can output Y16 (16 bit-per-pixel) mono images. However, the camera uses a 12-bit A/D converter (see the *Analog-to-Digital Converter* section), so only 12 bits of useable data is theoretically possible.

To determine the number of bits of useable image data, and resulting signal-to-noise ratio, that is actually being produced by the A/D converter, see www.ptgrey.com/support/kb/index.asp?a=4&q=170.

The data format for Y16 images is controlled by the *Y16_Data_Format* field of the IMAGE_DATA_FORMAT register 0x1048. Consult the *PGR IEEE-1394 Digital Camera Register Reference* for more information.

The PGM file format can be used to correctly save 16-bit images. However, 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.

4.5.10. Asynchronous (External) Trigger Modes

The *Flea2* provides a number of different asynchronous trigger modes, which allows the start of exposure (shutter) to be initiated by an external electrical source (hardware trigger) or camera register write (software trigger). Supported modes include: 0, 1, 3, 4, 5, 14 and 15. These modes and their operation are described in greater detail in the *PGR IEEE-1394 Digital Camera Register Reference*.

> *Asynchronous trigger modes 4 and 5 are supported only in the 03S2 and 08S2 models. These trigger modes are not compatible with the color binning support provided by other models.*

4.5.10.1. External Trigger Timing

The time from the external trigger going low to the start of shutter is shown below:

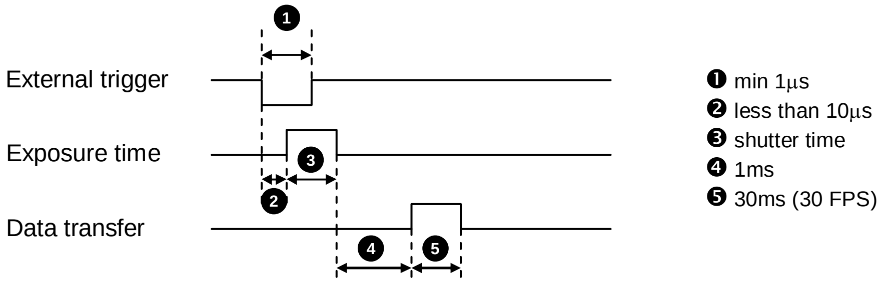


Figure 6: *Flea2* external trigger timing characteristics

It is possible for users to measure this themselves by configuring one of the camera's GPIO pins to output a strobe pulse (see the *Programmable Strobe Output* section) and connecting an oscilliscope up to the input trigger pin and the output strobe pin. The camera will strobe each time an image acquisition is triggered; the start of the strobe pulse represents the start of exposure.

4.5.10.2. Ensuring Trigger is Armed

It is possible for the *Flea2* to be in asynchronous trigger mode but not be ready to accept a trigger. The reason for this is that the camera may be currently exposing an image; the camera is only ready to be triggered again when this image finishes integrating and is completely read off of the CCD.

To ensure that the camera is ready to be triggered, poll the SOFTWARE_TRIGGER register 0x62C or SOFT_ASYNC_TRIGGER register 0x102C. The concept of polling to ensure the trigger is armed is demonstrated in the AsyncTriggerEx example program distributed with the *FlyCapture* SDK.

Once the the trigger is reporting that it is armed, there should be no delay between when the user can enable isochronous transmission and when they can trigger the camera. In fact, it is possible to trigger the camera before iso is enabled and receive the image that was triggered, provided iso is enabled at some point during exposure. For example, assuming a 10ms shutter time, it is possible to trigger the camera, enable iso 5ms after, and still receive the triggered image.

Related Knowledge Base Articles

ID	Title	URL
169	Time between software trigger and start of integration.	www.ptgrey.com/support/kb/index.asp?a=4&q=169
177	Maximum frame rate possible in external trigger mode_0.	www.ptgrey.com/support/kb/index.asp?a=4&q=177
221	Synchronizing to an external signal using DCAM 1.31 Trigger_Mode_0	www.ptgrey.com/support/kb/index.asp?a=4&q=221

4.5.10.3. Minimum Trigger Pulse Length

A digital signal debouncer helps to ensure that the camera does not respond to spurious electrical signals that are shorter than 16 ticks of the current pixel clock setting. This safeguard results in a minimum 16-tick delay before the camera responds to a trigger signal. The pixel clock frequency can be read from the floating point PIXEL_CLOCK_FREQ register 0x1AF0.

4.5.11. On-Camera Frame Buffer

The FL2G-13S2 and FL2G-50S5 models have 32MB of memory that can be used for temporary image storage. This may be useful in cases such as:

- Retransmission of an image is required due to data loss or corruption.
- Multiple camera systems where there is insufficient bandwidth to capture images in the desired configuration.

This feature is controlled using either of the following:

- The Frame Buffer register located at 0x12E8. For more information, see *TAN2007004: Accessing the On-Camera Frame Buffer*.
- The FlyCap Demo software. For more information, refer to the FlyCapture SDK online Help.

4.6. Image Processing

4.6.1. Color and Greyscale Conversion

In order to produce color (e.g. RGB, YUV) and greyscale (e.g. Y8, Y16) images, color *Flea2* models perform on-board processing of the Bayer Tile Pattern output produced by the CCD.

The conversion from RGB to YUV uses the following formula:

$$\begin{bmatrix} Y_{601} \\ C_B \\ C_R \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \frac{1}{256}\begin{bmatrix} 65.738 & 129.057 & 25.064 \\ -37.945 & -74.494 & 112.439 \\ 112.439 & -94.154 & -18.285 \end{bmatrix}\begin{bmatrix} R_{255} \\ G_{255} \\ B_{255} \end{bmatrix}$$

To convert the Bayer Tile Pattern to greyscale, the *Flea2* adds the value for each of the RGB components in the color processed pixel to produce a single greyscale (Y) value for that pixel, as follows:

$$Y = R/4 + G/2 + B/4$$

For a full description of how Bayer Tiled color sensors and color filter arrays work, refer to Knowledge Base Article 89 (http://www.ptgrey.com/support/kb/index.asp?a=4&q=89).

4.6.1.1. Accessing Raw Bayer Data

Users interested in accessing the raw Bayer data to apply their own color conversion algorithm or one of the FlyCapture library algorithms, should acquire images using one of the Format_7 video modes that support Raw8 or Raw16 pixel encoding. See the *Customizable Formats and Modes* section for further information on acquiring images using these modes. An alternative to this is to use the Bayer_Mono_Ctrl bit [24] of the IMAGE_DATA_FORMAT register 0x1048. Setting this bit to 1 enables raw Bayer output in non-Format_7 Y8 / Y16 modes, or Format_7 Mono8 / Mono16 modes.

The actual physical arrangement of the red, green and blue "pixels" for a given camera is determined by the arrangement of the color filter arrays on the imaging sensor itself. For example, the CFA format of a Sony ICX204AK color CCD can be found in the "Block Diagram and Pin Configuration" section of its datasheet. The format (i.e. order) in which this raw color data is streamed out, however, 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 FlyCaptureImage structure (e.g. FlyCaptureImage.pData). In Raw8 modes, the first byte represents the pixel at (row 0, column 0), the second byte at (row 0, column 1), etc. Read the BAYER_TILE_MAPPING register 0x1040 to determine the current Bayer output format (e.g. RGGB, GRBG, etc.). Using a Bayer format of RGGB, for example, if we access the image data via the pData pointer we would have the following:

- pData[0] = Row 0, Column 0 = red pixel (R)
- pData[1] = Row 0, Column 1 = green pixel (G)
- pData[640] = Row 1, Column 0 = green pixel (G)
- pData[641] = 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

4.6.2. Lookup Table and Gamma

The *Flea2* supports lookup table (LUT) and gamma functionality. CCD manufacturers strive to make the transfer characteristics of CCDs inherently linear, which means that as the number of photons hitting the imaging sensor increases, the resulting image intensity increases will be linear.

The *Flea2* has three (3) 11-bit input lookup tables that produce 9-bit outputs. Although the camera uses a 12-bit A/D converter, the *Flea2* is only able to accommodate 11-bit images. In normal color operation there is a separate LUT for red, green, and blue. The LUT therefore allows the user to map the 2^{11}, or 2048, different possible pixel values to any one of 512 (2^9) possible output values. For example, the LUT would allow the user to map any pixel with a value of 2047 (white) to any value between 0 (black) and 512 (white). For monochrome cameras, the LUT's are configured to operate as a single 11-bit input with three 9-bit outputs (mono to RGB). Color cameras in a monochrome (Y8) mode still require a three channel RGB LUT because the monochrome image comes from a weighted sum of the red, green and blue pixel values (see *Color and Greyscale Conversion*) after the LUT has been applied.

Gamma is applied after the analog-to-digital conversion and is controlled using the GAMMA register 0x818. It can be used to apply a non-linear mapping of the resulting 11-bit image down to 9 bits. By default, Gamma is OFF and has a value of 1.0, which yields a linear response. For more information regarding the LUT CSR registers, refer to the *PGR IEEE-1394 Digital Camera Register Reference*.

Lookup table functionality is not supported on color cameras when the camera is in a raw Bayer output mode, such as Format_7 Raw8 or Raw16 modes.

4.6.3. Saturation

The *Flea2* supports saturation, which refers to color saturation, as opposed to saturation of a CCD charge. Saturation is controlled using the SATURATION register 0x814

4.6.4. Sharpness

The *Flea2* supports sharpness, which refers to the filtering of an image to reduce blurring at image edges. Sharpness is implemented as an average upon a 3x3 block of pixels, and is only applied to the green component of the Bayer tiled pattern. For sharpness values greather than 1000, the pixel is sharpened; for values less than 1000 it is blurred. When sharpness is in auto mode, if gain is low, then a small amount of shaping is applied, which increases as gain decreases. If the gain is high, a small amount of blur is applied, increasing as gain increases.

4.6.5. White Balance

The *Flea2* supports white balance, which is a name given to 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.

The *Flea2* also implements Auto and One_Push white balance. One of the uses of one_push / auto white balance is to obtain a similar color balance between different cameras that are slightly different from each other. Theoretically, if different cameras are pointed at the same scene, using one_push / auto will result in a similar color balance between the cameras.

One_push is similar identical to auto white balance, except One-Push only attempts to automatically adjust white balance for a set period of time before stopping. The white balance of the camera before using One-Push/Auto must already be relatively close, i.e. if Red is set to 0 and Blue is at maximum (two extremes), One-Push/Auto will not work. However, if the camera is already close to being color balanced, then it will work (it may only be a small change).

One_push only attempts to automatically adjust white balance for a set period of time before stopping. It uses a "white detection" algorithm that looks for "whitish" pixels in the raw Bayer image data. One_push adjusts the white balance for a specific number of iterations; if it cannot locate any whitish pixels, it will gradually look at the whitest objects in the scene and try to work off them. It will continue this until has completed its finite set of iterations.

Auto is continually adjusting white balance. It differs from one_push in that it works almost solely off the whitest objects in the scene.

4.6.6. Image Flip / Mirror

The *Flea2* supports horizontal image mirroring. The mirror image operation is done on the camera using the on-board frame buffer, and is controlled using the IMAGE_DATA_FORMAT register 0x1048, which is described in detail in the *PGR IEEE-1394 Digital Camera Register Reference*.

4.6.7. Test Pattern

The *Flea2* is capable of outputting a continuous static image for testing and development purposes. The test pattern image is inserted into the imaging pipeline immediately prior to the transfer to the on-board FIFO, and is therefore not subject to changes in hue, saturation, sharpness, white balance or gamma. Test pattern support is only available for Y8, Y16 and YUV422 video modes. The test pattern is a simple 8 bit-per-pixel counter (the pixel intensities in each column increment from 0 to 255).

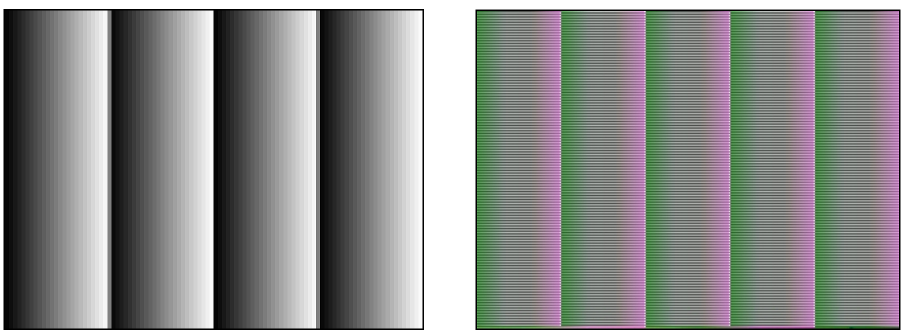


Figure 7: Test pattern sample image (Mono and YUV formats)

The test pattern can be enabled using the TEST_PATTERN register 0x104C, which is described in detail in the *PGR IEEE-1394 Digital Camera Register Reference*.

4.6.8. Embedded Image Information

The *Flea2* 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 *PGR IEEE-1394 Digital Camera Register Reference*.

4.7. Camera and Device Control

4.7.1. Voltage Sensor

The *Flea2* has an on-board sensor that allows the user to monitor a variety of different voltages, including the current 1394 bus voltage. This feature can be accessed using the VOLTAGE registers 0x1A50 – 0x1A54, which are described in detail in the *PGR IEEE-1394 Digital Camera Register Reference*.

4.7.2. Programmable Strobe Output

The *Flea2* 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 *Flea2* 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

4.7.3. RS-232 Serial Port

The *Flea2* 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

4.7.4. Memory Channel Storage of Camera Settings

The *Flea2* 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 *Flea2* 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.

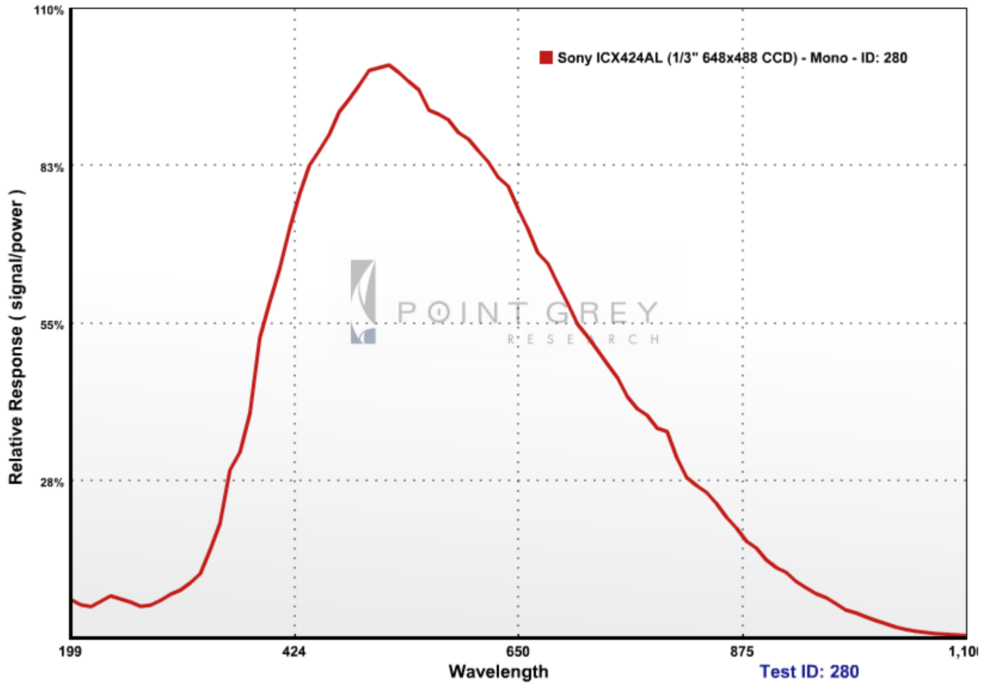
Memory channels are configured using the following registers, which are described in detail in the *PGR IEEE-1394 Digital Camera Register Reference*: MEMORY_SAVE 0x618; MEM_SAVE_CH 0x620; and CUR_MEM_CH 0x624.

4.7.5. Camera Upgrades

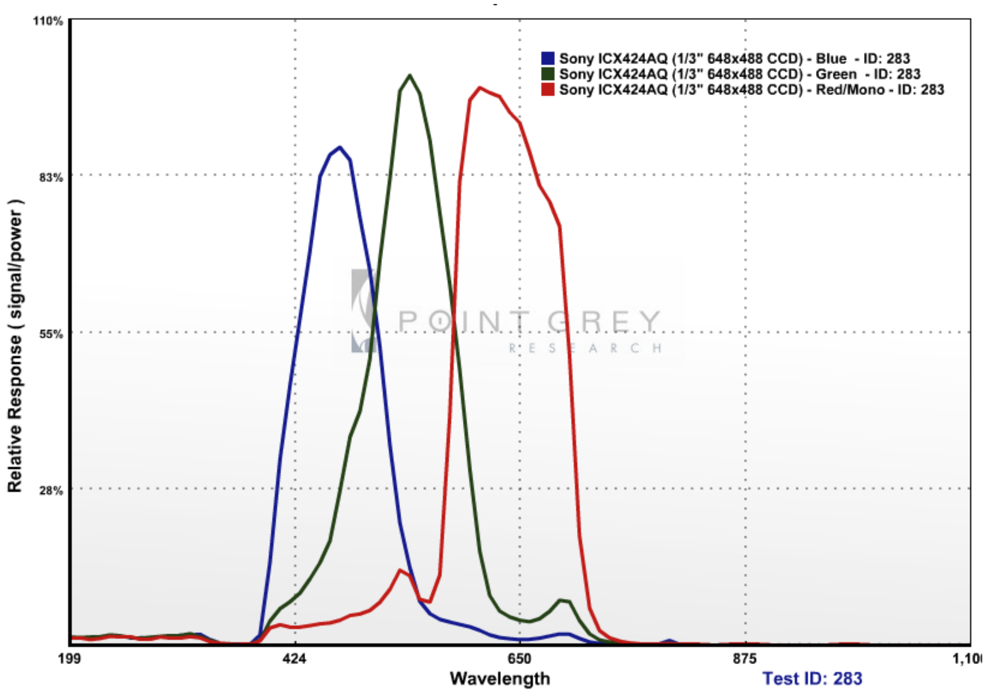
The firmware on the *Flea2* can be upgraded / downgraded to later / earlier versions using the UpdatorGUI program that is bundled with every firmware version available from www.ptgrey.com/support/downloads/. The latest firmware versions often include significant bug fixes and feature enhancements that 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: Spectral Response Curves

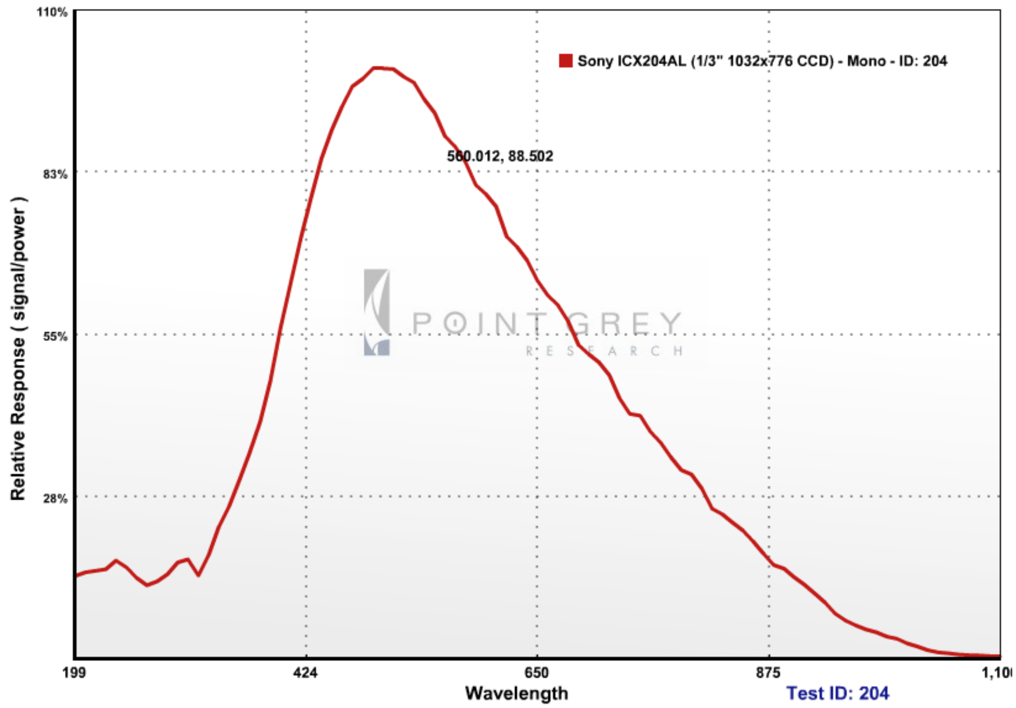
FL2-03S2M



FL2-03S2C



FL2-08S2M



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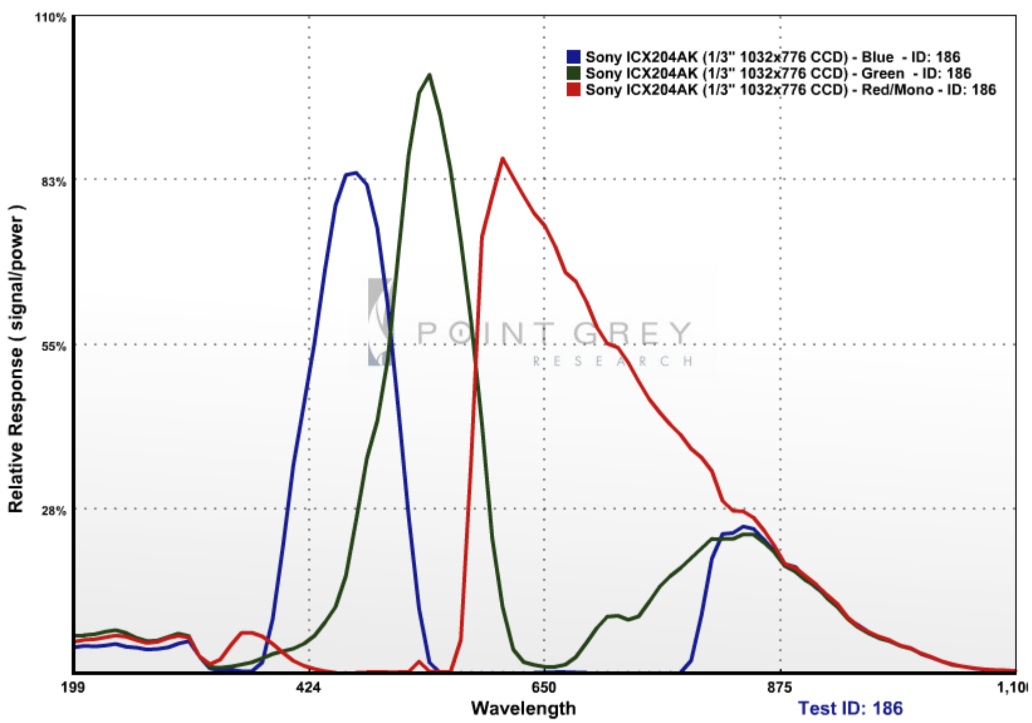
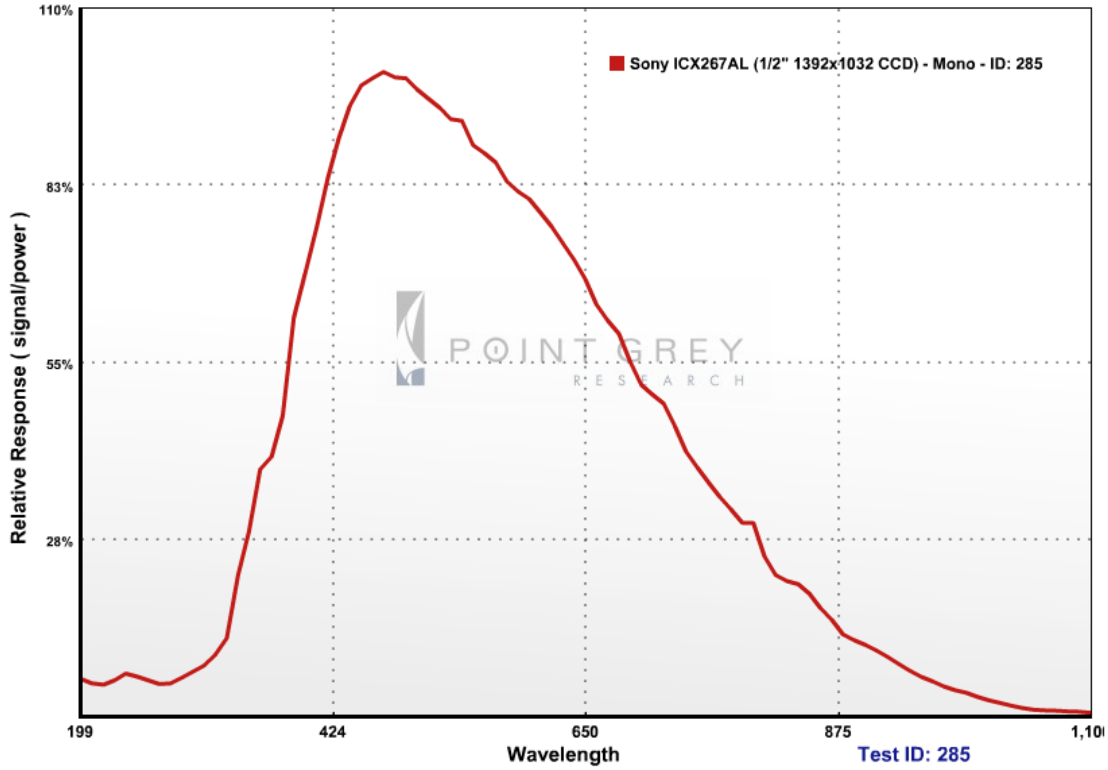
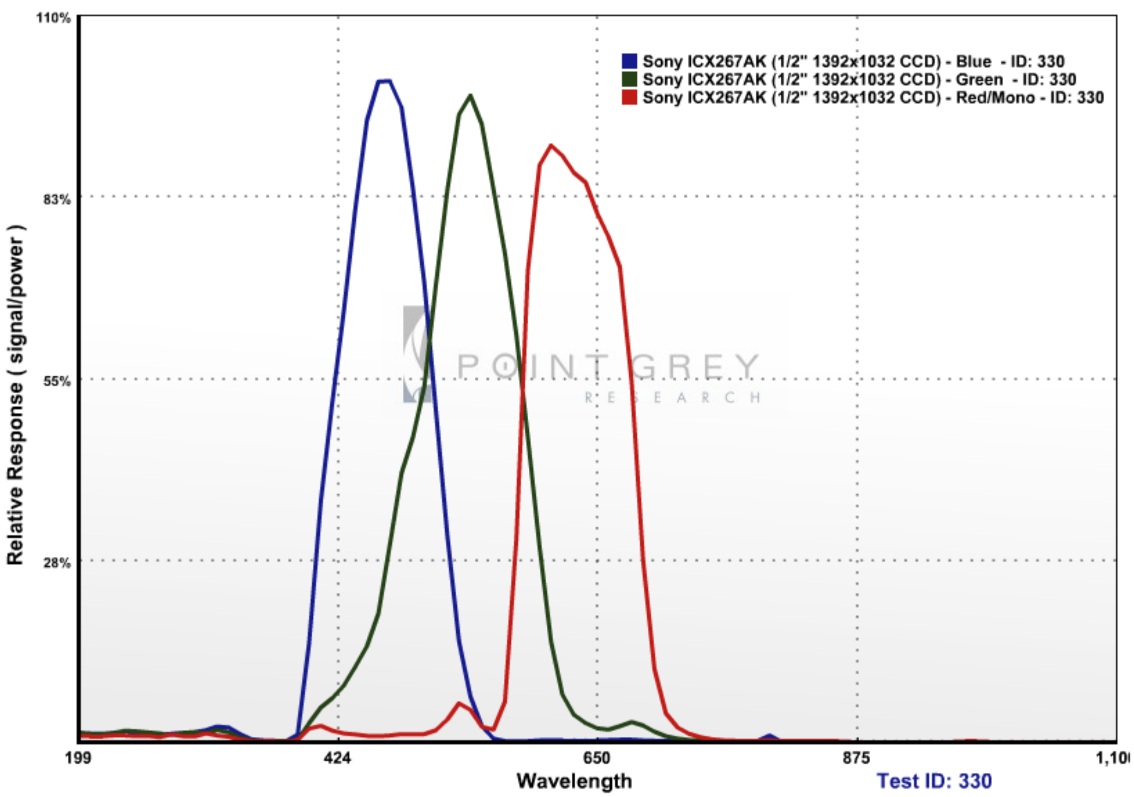


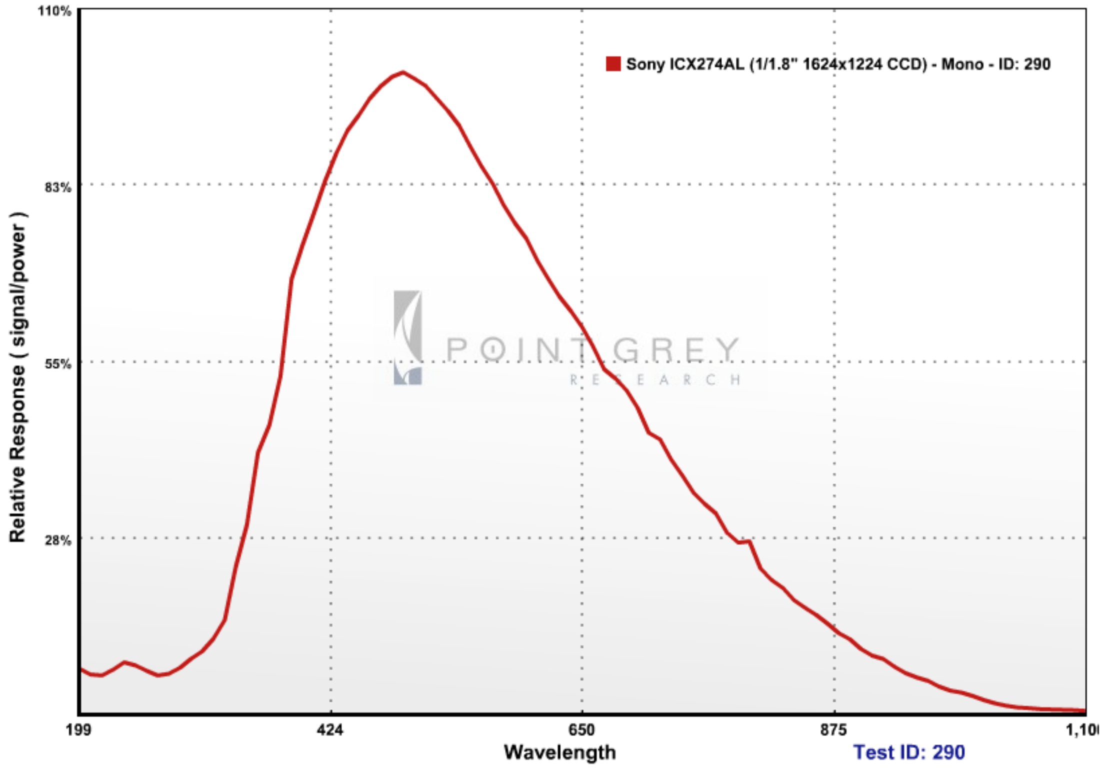
FL2-14S3M



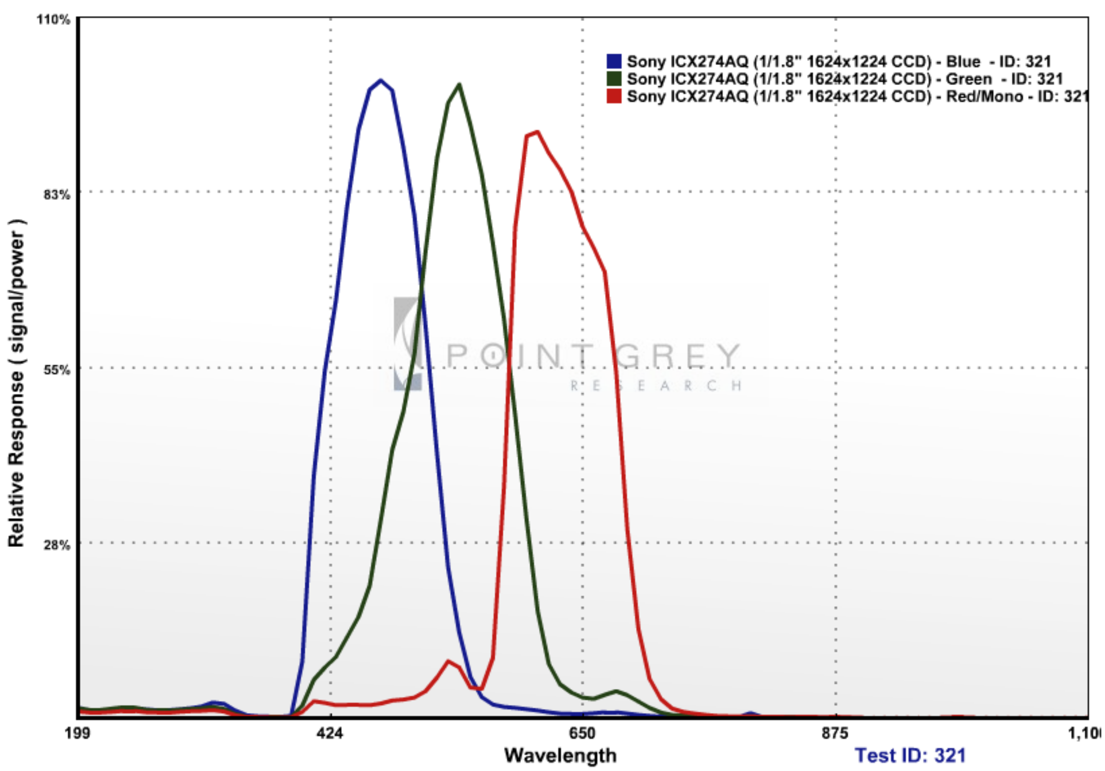
FL2-14S3C



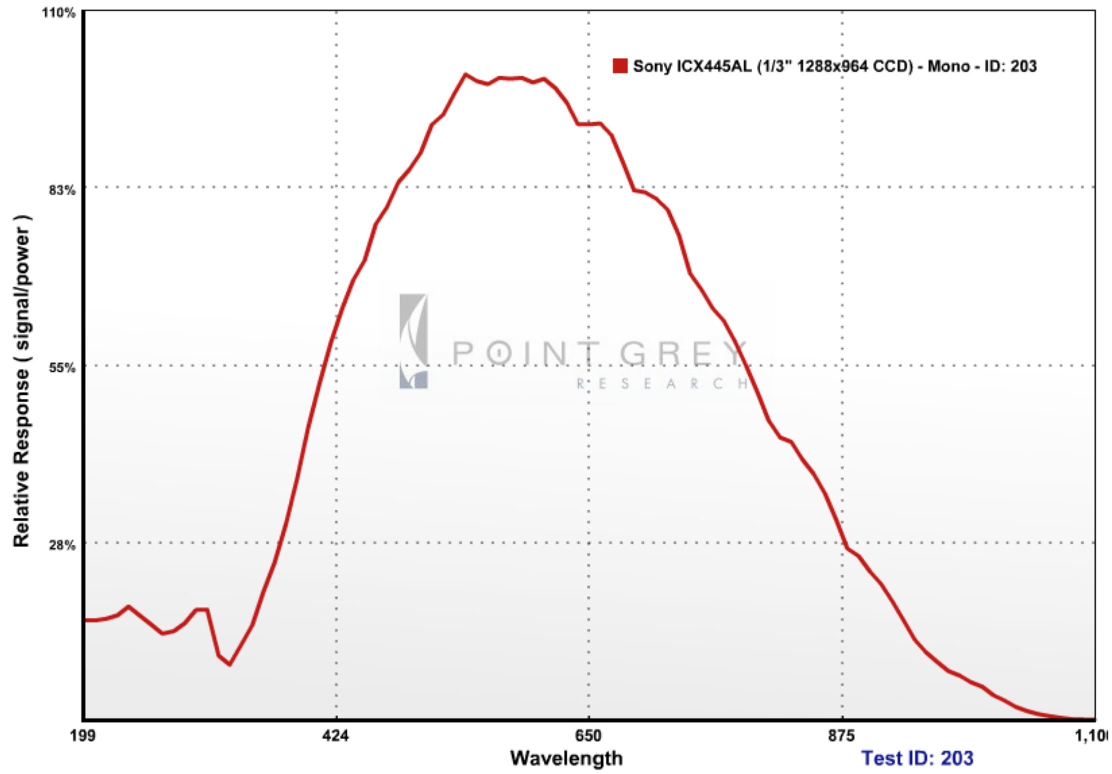
FL2-20S4M



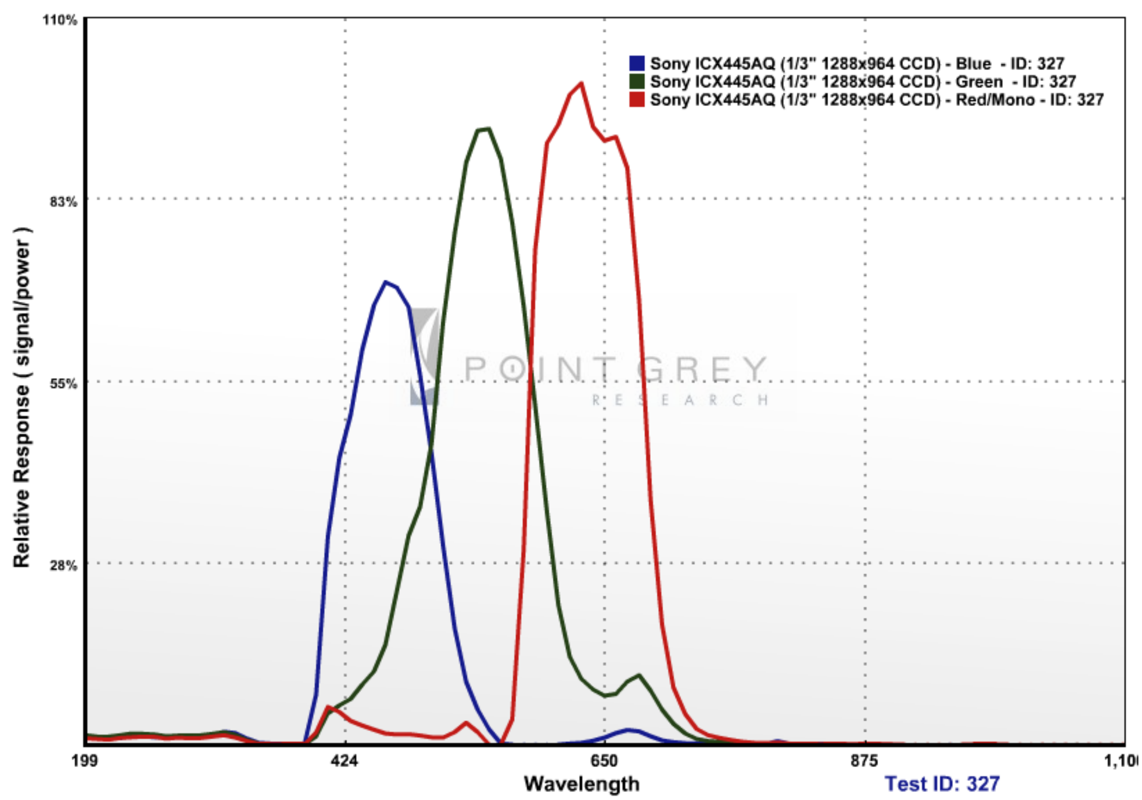
FL2-20S4C



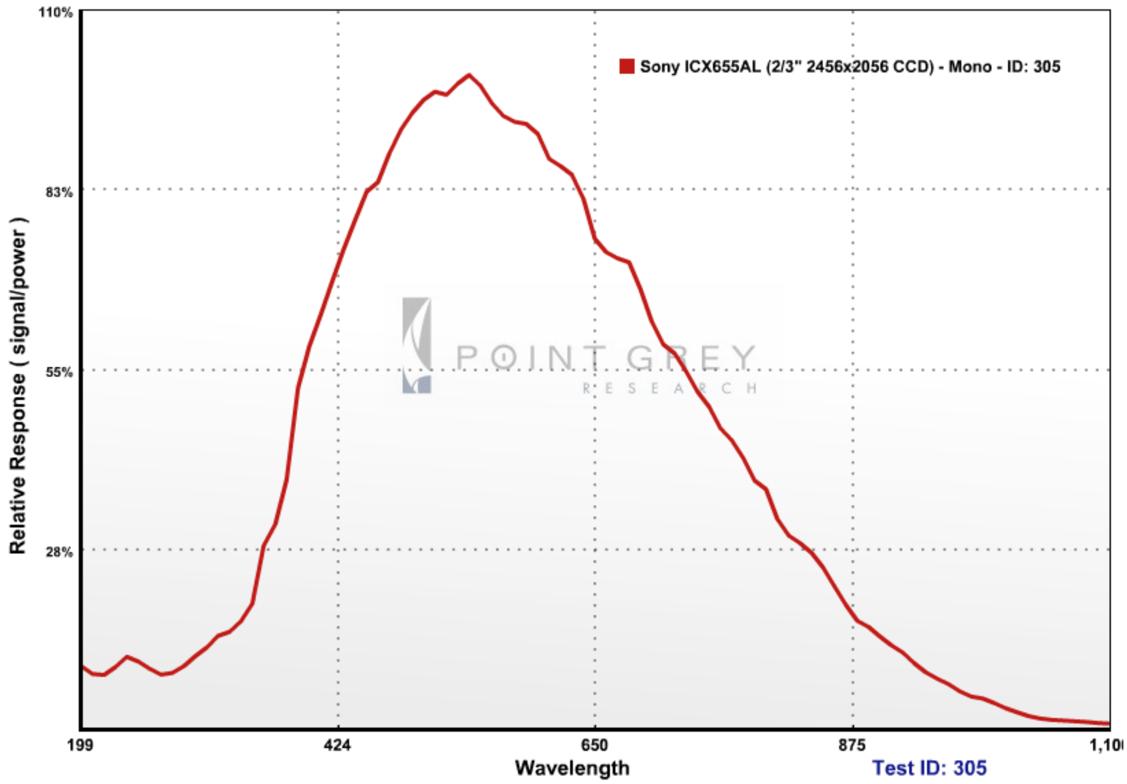
FL2G-13S2M



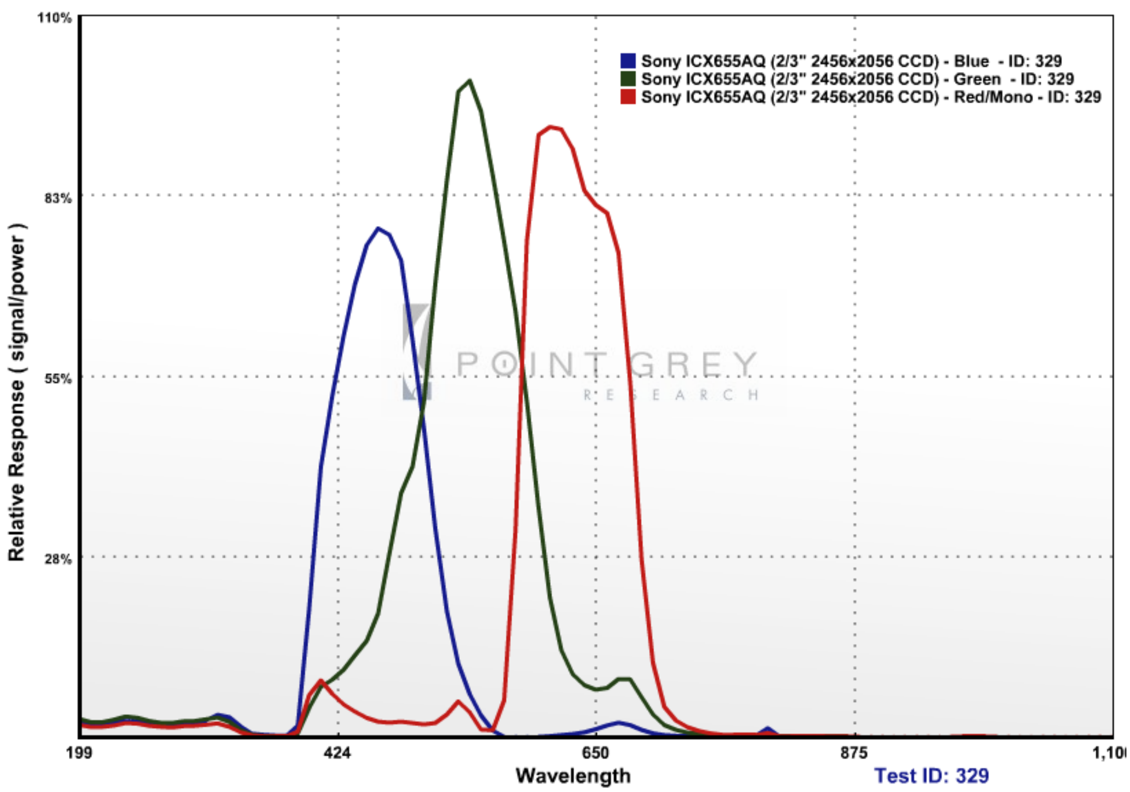
FL2G-13S2C



FL2G-50S5M



FL2G-50S5C



Appendix B: 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 C: 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 D: 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 E: 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/	
Main Office:	**Mailing Address:** Point Grey Research, Inc. 12051 Riverside Way Richmond, BC, Canada V6W 1K7	**Tel:** +1 (604) 242-9937 **Toll-free** (North America only)**:** +1 (866) 765-0827 **Fax:** +1 (604) 242-9938 sales@ptgrey.com
Distributors		
USA	**Tel:** +1 (866) 765-0827 na-sales@ptgrey.com	
Europe Israel	**Mailing Address:** Point Grey Research GmbH Schwieberdinger Strasse 60 71636 Ludwigsburg Germany	**Tel:** +49 7141 488817-0 **Fax:** +49 7141 488817-99 eu-sales@ptgrey.com
Japan	ViewPLUS Inc. (http://www.viewplus.co.jp/)	
Korea	Cylod Co. Ltd. (http://www.cylod.com)	
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 F: Revision History

Revision	Date	Notes
1.3	October 11, 2007	• Added Revision History to appendix • FL2-14S3 max frame correction to 15FPS • Signal-to-noise ratio updates • Clarification on bayer tile mapping

1.4	August 29, 2008	• Added information about FL2G models to the following sections:
		  • 1.3 Camera specifications
		  • 3.5 GPIO
		  • 4.2 Standard Data Formats & Modes
		  • 4.4 Customizable Data Formats & Modes
		  • 4.5.5 Extended Shutter Times
		• Added Section 4.5.11 to describe on-camera frame buffer of FL2G models.
		• Added support for asynchronous trigger mode 15, introduced with firmware v0.9.0.4.
		• Clarified that 14S3C and 20S4C models do not support asynchronous trigger modes 4 or 5.
		• Added that color binning is supported in the 14S3C and 20S4C models
		• Updated title page and Appendix D with new company address and phone.

1.5	September 23, 2008	• Clarified that asynchronous trigger modes 4 and 5 are supported only in 03S2 and 08S2 models. • Section 4.2: Clarified Standard Formats, Modes, and Frame Rates available on 20S4C model. • Replaced 1394b connector diagram in Section 3.1. Previous diagram portrayed the connector on a 1394b cable, rather than the camera.
1.6	October 29, 2008	• Section 2.6: Infrared Cut-Off Filters: Replaced generic IR filter transmittance graph with one obtained by Point Grey Research independent of camera model. • Section 4.1 General Camera Properties: Clarified that maximum trigger delay is 65 seconds. • Section 4.4: Customizable Data Formats and Modes. Clarified Format_7 frame rates of FL2G-13S2 and FL2G-50S5 models. • Added new Appendix (as Appendix A): Spectral Response Curves
1.7	February 20, 2009	• Section 3.5 General Purpose I/O: Clarified GND pinout of FL2G GPIO. • Updated Appendix C Glossary with new terms.

1.8	September 3, 2009	• Glossary: Fixed error in 1394b definition. • Section 4.5.10.3 Minimum Trigger Pulse Length: Added that for trigger mode 5 to work properly, minimum pulse width should be at least 15 µs. • Clarified that power input voltage range is 8-30 volts. • Clarified maximum resolution of FL2G-13S2 is 1288 x 964. • Section 2.3 Lens Setup and Compatibility, added a lens mount dimensional diagram and information about the back focal distance measurement. • Section 2.6 Infrared Cut-Off Filters, added information about the properties of the filter.
1.9	March 8, 2010	• Section 4.1 General Camera Properties: Fixed errors in table. • Section 4.5.8 Pixel Binning and Region of Interest Modes: Expanded the description of how binning works. • Section 4.2 Standard Data Formats, Modes and Frame Rates: Clarified supported modes of FL2-03S2M/C at 60 FPS. • Section 1.3 Camera Specifications: Added photon transfer curve measurements for 03S2 and 08S2 models. • Section 1.3.2 Analog-to-Digital Converter: Clarified that 12-bit image data is left aligned.
1.10	June 10, 2011	• Section 1.3 Camera Specifications: Updated photon transfer test rest result specifications for FL2-20S4. • Section 4.6.1 Color and Greyscale Conversion: Updated formula for converting from RGB to YUV. • Section 4.5.10.3: Minimum Trigger Pulse Length: Clarified the role of the signal debouncer.

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