Firefly® MV

Technical Reference Manual

Version 1.3
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Point Grey Research® Inc.
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For customers in the U.S.A.

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.

The shielded interface cable recommended in this manual must be used with this equipment in order to comply with the limits for a computing device pursuant to Subpart J of Part 15 of FCC Rules.

Hardware Warranty

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

Point Grey Research, Inc. expressly disclaims and excludes all other warranties, express, implied and statutory, including, but without limitation, warranty of merchantability and fitness for a particular application or purpose. In no event shall Point Grey Research, Inc. be liable to the Original Purchaser or any third party for direct, indirect, incidental, consequential, special or accidental damages, including without limitation damages for business interruption, loss of profits, revenue, data or bodily injury or death.

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

All model-specific information presented in this manual reflects functionality available in the following camera firmware version:

FFMV-03M2M/C: 0.9 Release Candidate 12

FMVU-03MTM/C: 0.9 Release Candidate 12

FMVU-13S2C: 1.2 Release Candidate 2

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

1.1. Using This Manual

This manual attempts to provide the user with a detailed specification of the *Firefly MV* 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.

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 user manuals, technical references and application notes, which can be downloaded from our website at www.ptgrey.com/support/downloads/:

- *Point Grey Digital Camera Register Reference*
- *FlyCapture SDK Help*

1.2. Camera Specifications

1.2.1. FFMV-03M2M/C Specifications

Imaging Sensor	Micron 1/3" Wide-VGA CMOS
	MT9V022177ATM (BW) MT9V022177ATC (Color)
Shutter Type	Global shutter using Micron TrueSNAP™ technology
Active Imager Size	4.51mm (H) x 2.88m (V), Diagonal 5.35mm (1/3" type)
Active Pixels	752(H) x 480(V)
Pixel Size	6µm(H) x 6µm(V)
A/D Converter	On-chip 10-bit analog-to-digital converter
Video Data Output	8 and 16-bit digital data (see *Supported Data Formats* below)
Standard Resolutions	640x480
Frame Rates[1]	60, 30, 15, 7.5 FPS
Partial Image Modes	Pixel binning and region of interest modes available via Format_7
Interfaces	6-pin IEEE-1394a for camera control, video data transmission and power
	7-pin JST GPIO connector, 4 pins for trigger and strobe, 1 pin +3.3 V, 1 V_{EXT} pin for external power
Voltage Requirements	8-32V via IEEE-1394 cable or GPIO connector (V_{EXT})
Power Consumption	Less than 1W
Gain	Automatic/Manual Gain modes
	0dB to 12dB
Shutter	Automatic/Manual Shutter modes
	0.03 ms to 512 ms (extended shutter mode)
Gamma	0 to 1 (enables 12-bit to 10-bit companding)
Trigger Modes	IIDC v1.31 Trigger Modes 0 and 3
Signal To Noise Ratio	52 dB
Dimensions	44 mm x 34 mm x 24.38 mm (case enclosed)
Mass	37 grams (including tripod adapter)
Camera Specification	IIDC 1394-based Digital Camera Specification v1.31
Emissions Compliance	Complies with CE rules and Part 15 Class B of FCC Rules.
Operating Temperature	Commercial grade electronics rated from 0° - 45°C
Storage Temperature	-30° - 60°C
Operating Relative Humidity	20 to 80% (no condensation)
Storage Relative Humidity	20 to 95% (no condensation)

[1] Using standard non-Format_7 video formats and modes.

1.2.2. FMVU-03MTM/C Specifications

Imaging Sensor	Micron 1/3" Wide-VGA CMOS
	MT9V022177ATM (BW) MT9V022177ATC (Color)
Shutter Type	Global shutter using Micron TrueSNAP™ technology
Active Imager Size	4.51mm (H) x 2.88m (V), Diagonal 5.35mm (1/3" type)
Active Pixels	752(H) x 480(V)
Pixel Size	6µm(H) x 6µm(V)
A/D Converter	On-chip 10-bit analog-to-digital converter
Video Data Output	8 and 16-bit digital data (see *Supported Data Formats* below)
Standard Resolutions	640x480
Frame Rates[2]	60, 30, 15, 7.5 FPS
Partial Image Modes	Pixel binning and region of interest modes available via Format_7
Interfaces	5-pin Mini-B USB 2.0 for camera control, video data transmission and power
	7-pin JST GPIO connector, 4 pins for trigger and strobe, 1 pin +3.3 V, 1 V_{EXT} pin for external power
Voltage Requirements	4.75 to 5.25 V via the Mini-B USB 2.0 cable or JST 7-pin GPIO connector
Power Consumption	Less than 1W
Gain	Automatic/Manual Gain modes
	0dB to 12dB
Shutter	Automatic/Manual Shutter modes
	0.03 ms to 512 ms (extended shutter mode)
Gamma	0 to 1 (enables 12-bit to 10-bit companding)
Trigger Modes	IIDC v1.31 Trigger Modes 0 and 3
Signal To Noise Ratio	52 dB
Dimensions	44 mm x 34 mm x 24.38 mm (case enclosed)
Mass	37 grams (including tripod adapter)
Camera Specification	IIDC 1394-based Digital Camera Specification v1.31
Emissions Compliance	Complies with CE rules and Part 15 Class B of FCC Rules.
Operating Temperature	Commercial grade electronics rated from 0° - 45°C
Storage Temperature	-30° - 60°C
Operating Relative Humidity	20 to 80% (no condensation)
Storage Relative Humidity	20 to 95% (no condensation)

[2] Using standard non-Format_7 video formats and modes.

1.2.3. FMVU-13S2C Specifications

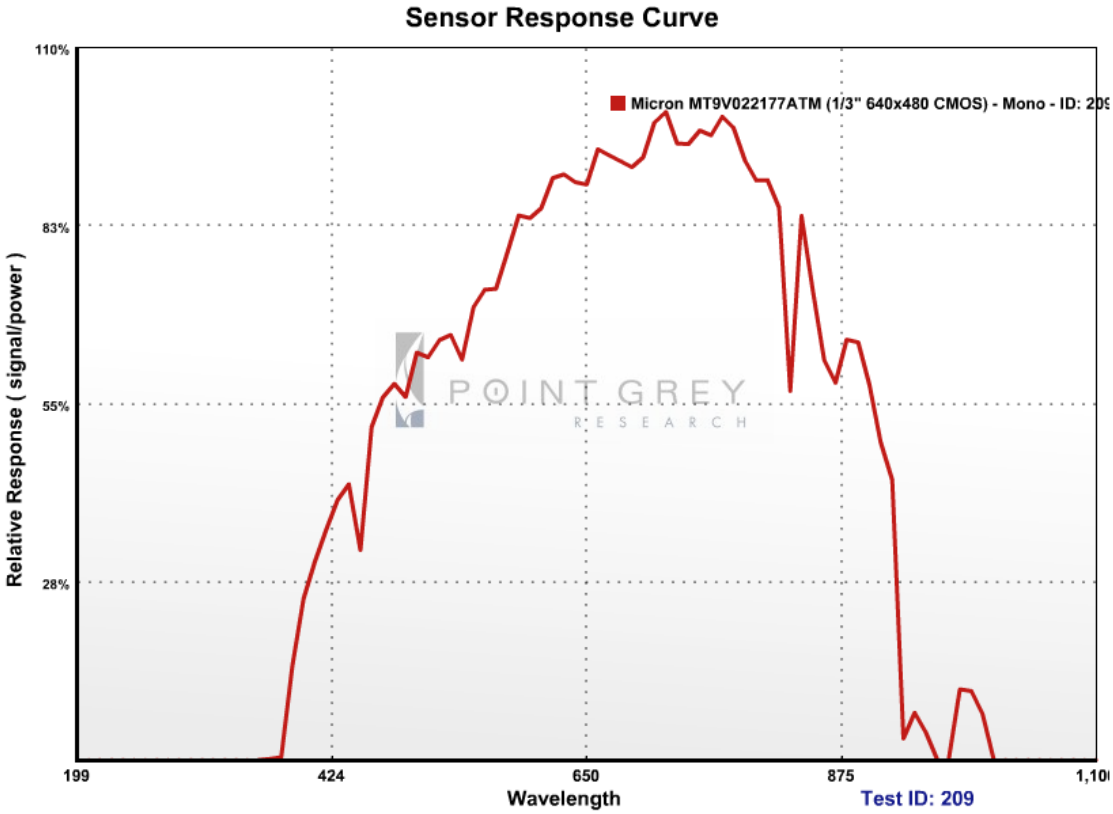
Imaging Sensor	Sony 1/3" CMOS
	IMX035LQR-C (Color)
Shutter Type	Rolling shutter
Active Imager Size	7.64 mm (H) x 7.64 mm (V), Diagonal 6.08 mm (1/3" type)
Active Pixels	1328 (H) x 1048 (V)
Pixel Size	3.63 µm (H) x 3.63 µm(V)
A/D Converter	10/12-bit
Video Data Output	8 and 16-bit digital data (see *Supported Data Formats* below)
Standard Resolutions	640x480, 1280x960
Frame Rates[3]	60, 30, 15, 7.5 FPS
Partial Image Modes	Pixel binning or center cut-out (640x480) mode via Format_7
Interfaces	5-pin Mini-B USB 2.0 for camera control, video data transmission and power
	7-pin JST GPIO connector, 4 pins for trigger and strobe, 1 pin +3.3 V, 1 V_{EXT} pin for external power
Voltage Requirements	4.75 to 5.25 V via the Mini-B USB 2.0 cable or JST 7-pin GPIO connector
Power Consumption	Less than 1W
Gain	Automatic/Manual Gain modes
	0dB to 18dB
Shutter	Automatic/Manual Shutter modes
	0.12 ms to 8000 ms (extended shutter mode)
Gamma	512 to 4095
Trigger Modes	IIDC v1.31 Trigger Modes 0 and 3
Signal To Noise Ratio	66 dB
Dimensions	44 mm x 34 mm x 24.38 mm (case enclosed)
Mass	37 grams (including tripod adapter)
Camera Specification	IIDC 1394-based Digital Camera Specification v1.31
Emissions Compliance	Complies with CE rules and Part 15 Class B of FCC Rules.
Operating Temperature	Commercial grade electronics rated from 0° - 45°C
Storage Temperature	-30° - 60°C
Operating Relative Humidity	20 to 80% (no condensation)
Storage Relative Humidity	20 to 95% (no condensation)

[3] Using standard non-Format_7 video formats and modes.

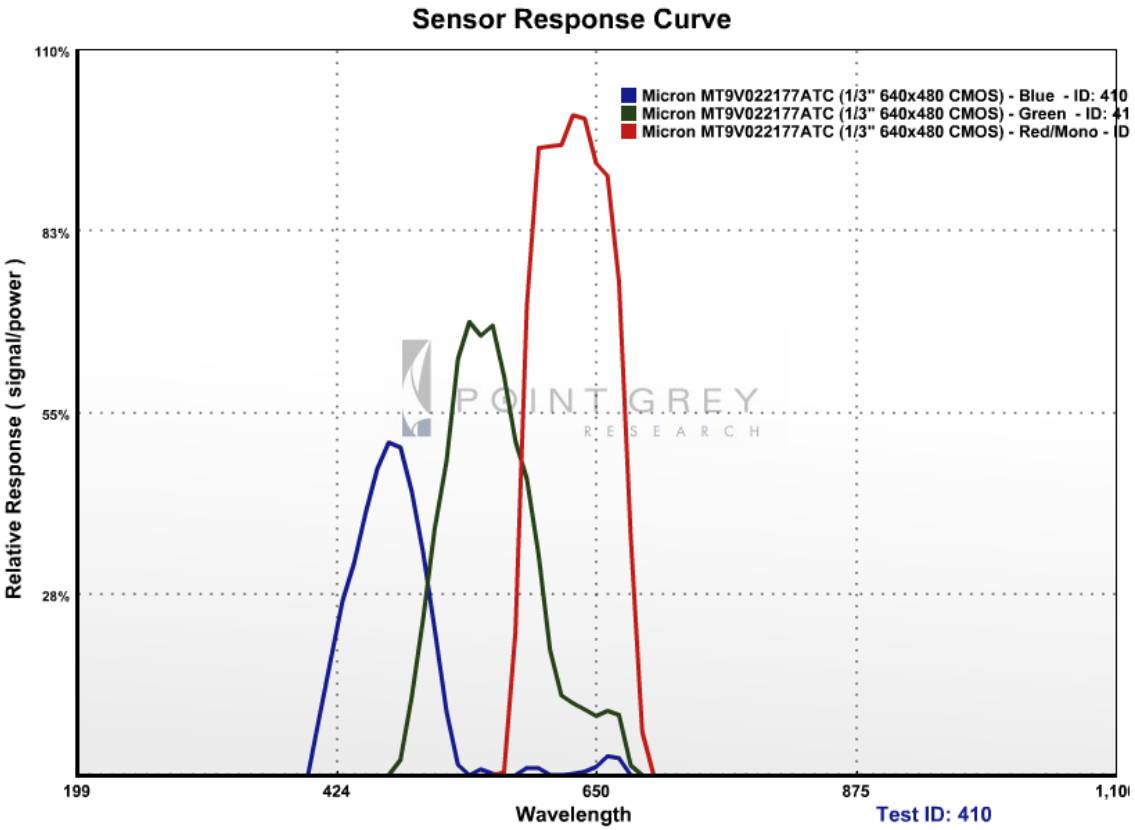
1.2.4. Spectral Response

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.

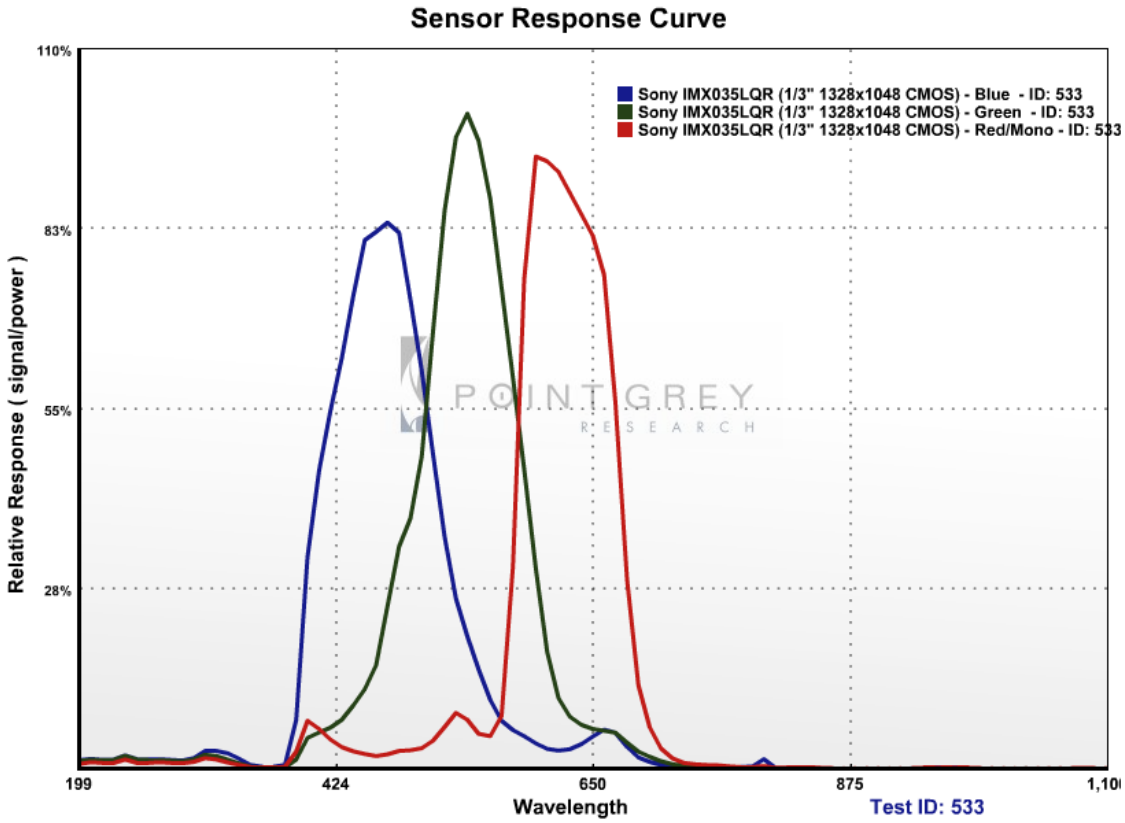
1.2.4.1. FFMV-03M2M & FMVU-03MTM Spectral Response



1.2.4.2. FFMV-03M2C & FMVU-03MTC Spectral Response



1.2.4.3. FMVU-13S2C Spectral Response



1.2.5. Analog-to-Digital Converter

Both the Micron MT9V022177ATM and Sony IMX035LQR sensors include an on-board A/D converter to digitize the images produced by the CMOS. The following tables illustrate the most important aspects of these processors.

Resolution	10-bit, 27 MHz
Variable Gain Amplifier	0 dB to 12 dB
Black Level Clamp	0 to 255

Table 1: Micron MT9V022177ATM (FFMV-03M2M/C & FMVU-O3MTM/C) A/D Properties

Resolution	10/12-bit, 54 MHz
Variable Gain Amplifier	0 dB to 24 dB
Pixel Gain Amplifier	0 dB to 18 dB
Black Level Clamp	0 to 511

Table 2: Sony IMX035LQR (FMVU-13S2) A/D Properties

1.3. 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)

1.3.1. 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 IEEE-1394a 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

1.3.2. 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

1.4. Controlling the Camera

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

1.4.1. 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 Point Grey 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 Point Grey camera system. Consult the *Point Grey FlyCapture User Manual* for more information.

1.4.2. 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.

1.4.3. 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

1.4.4. Custom Applications Built with other APIs

The FlyCapture SDK supports custom applications built with DirectShow, TWAIN and ActiveX components. An ActiveX Programming Reference is installed by default in the Start menu at Point Grey Research → PGR FlyCapture → Documentation.

1.5. 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/.

1.6. 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.

1.6.1. Heat Dissipation

The plastic case of the *Firefly MV* does not get hot. Nevertheless, the camera can generate significant heat, especially when running in some high data rate video modes. A high-quality lens with a metal housing, in conjunction with the lens mount, can act as an effective heat sink. As such, the lens and lens mount may become very warm to the touch. This is expected behaviour and will not cause damage. If reducing heat is a concern, use a cooling fan to set up a positive air flow around the camera, while ensuring there is enough open space around the camera to facilitate the free flow of air.

1.7. Camera Accessories

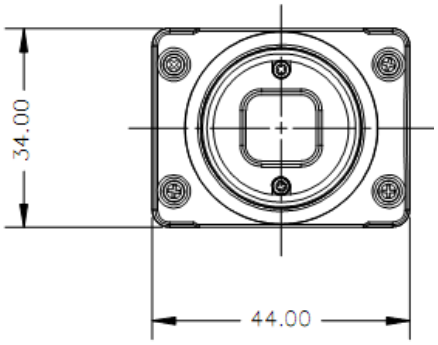
Accessories such as tripod mounts and lens holders are available from PGR – contact our Sales team at sales@ptgrey.com for additional information. Links to FireWire/IEEE-1394 and digital camera accessories can be found in the following knowledge base article:

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

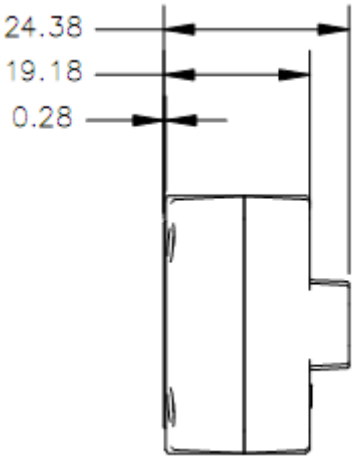
2 Camera Physical Properties

2.1. Physical Description and Dimensions

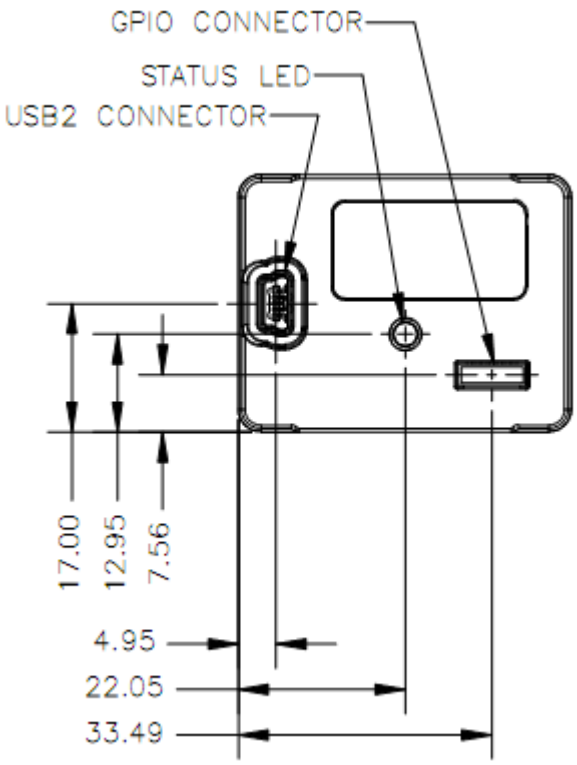
2.1.1. FMVU-03S2 and FMVU-13S2 Dimensions



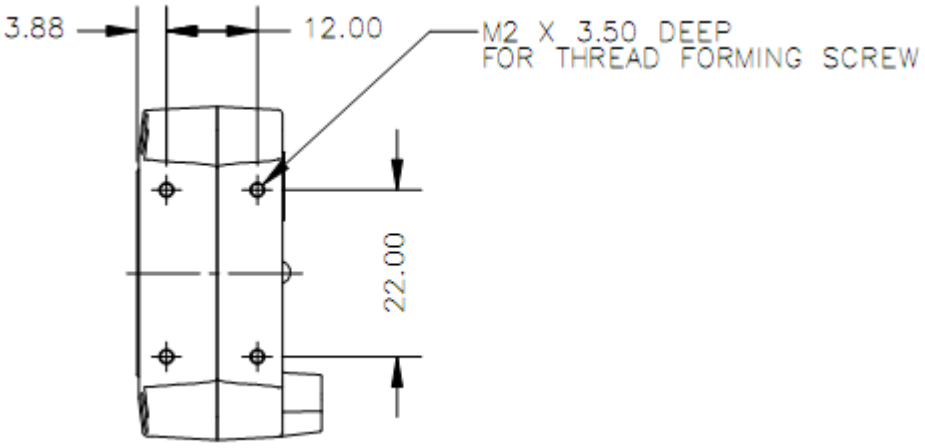
Front View



Side View with USB Connector

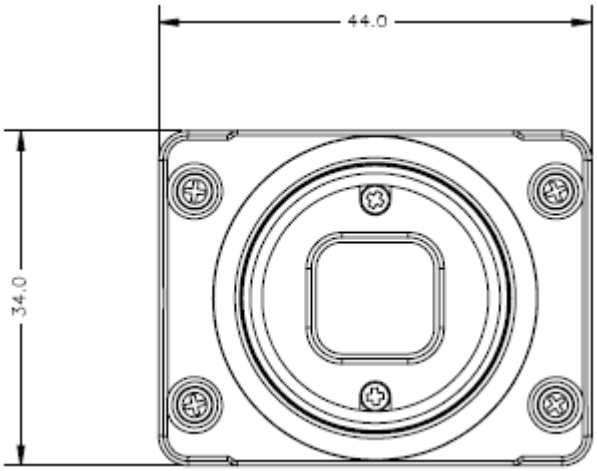


Rear View with USB 2.0 Connector

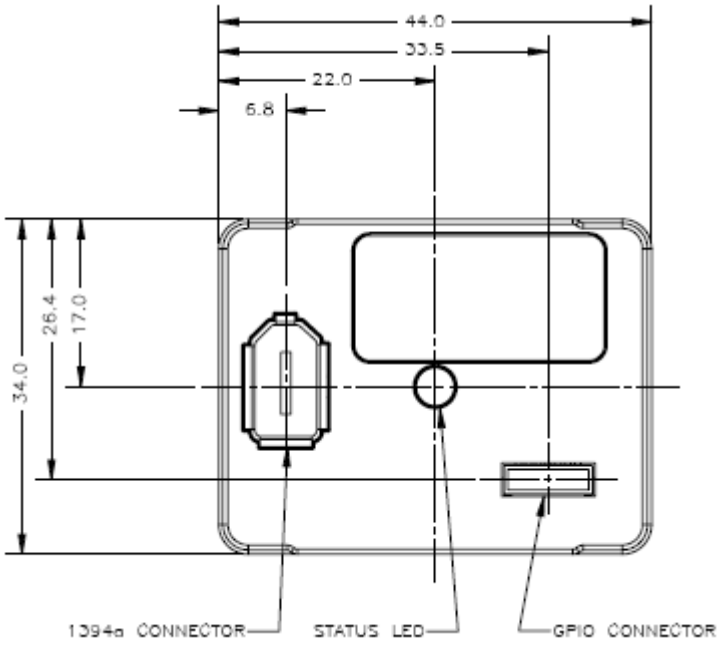


Top View with USB Connector

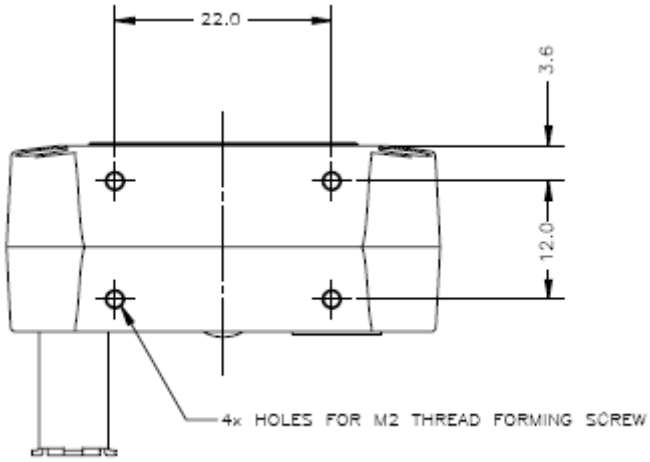
2.1.2. FFMV-03M2 Dimensions



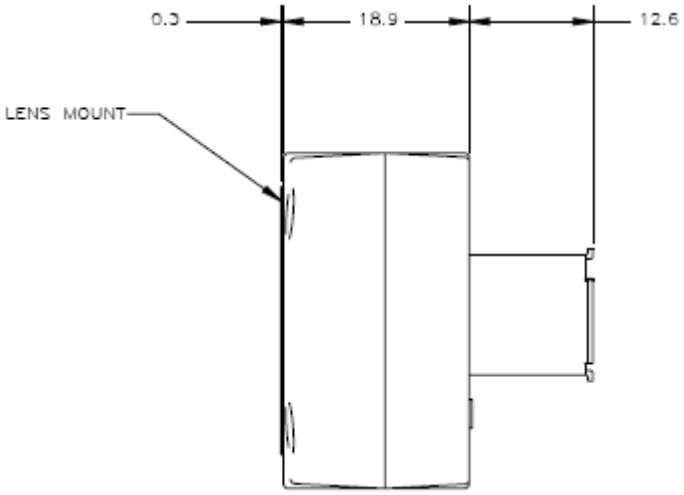
Front View



Rear View with 1394a Connector



Top View with 1394a Connector

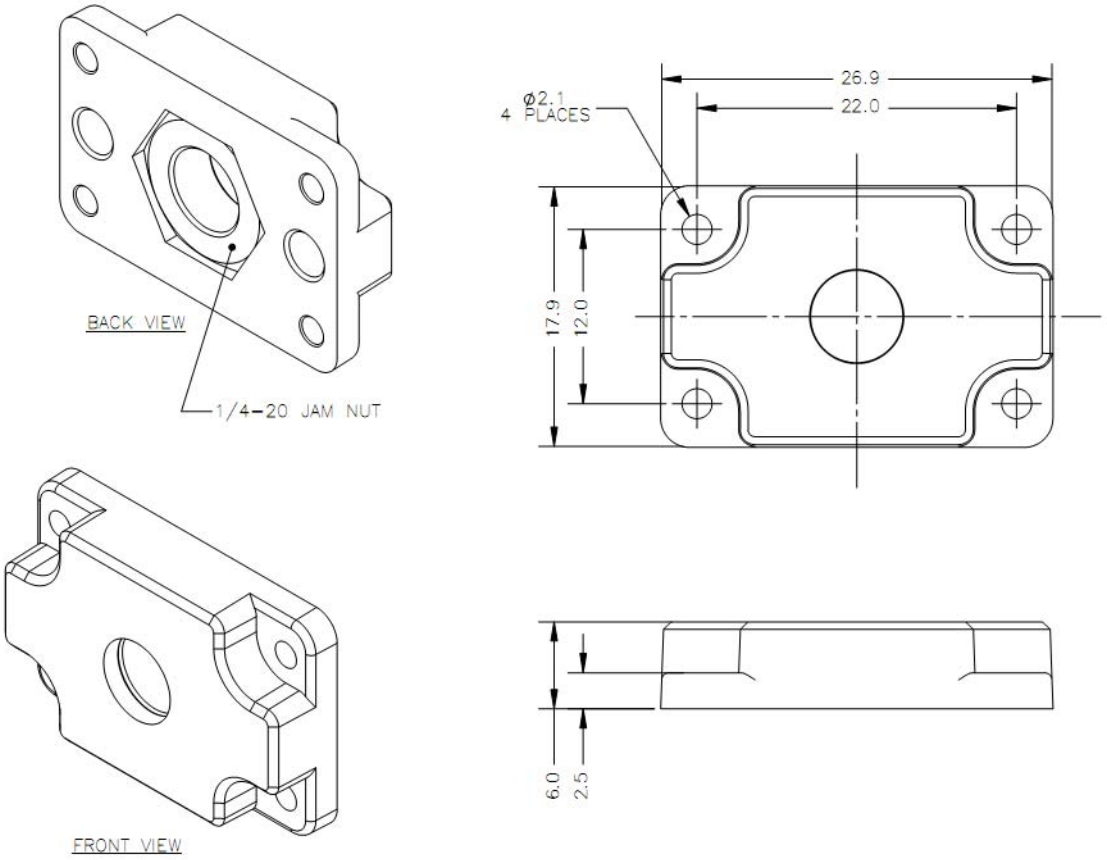


Side View with 1394a Connector

2.1.3. Board-Level Dimensions

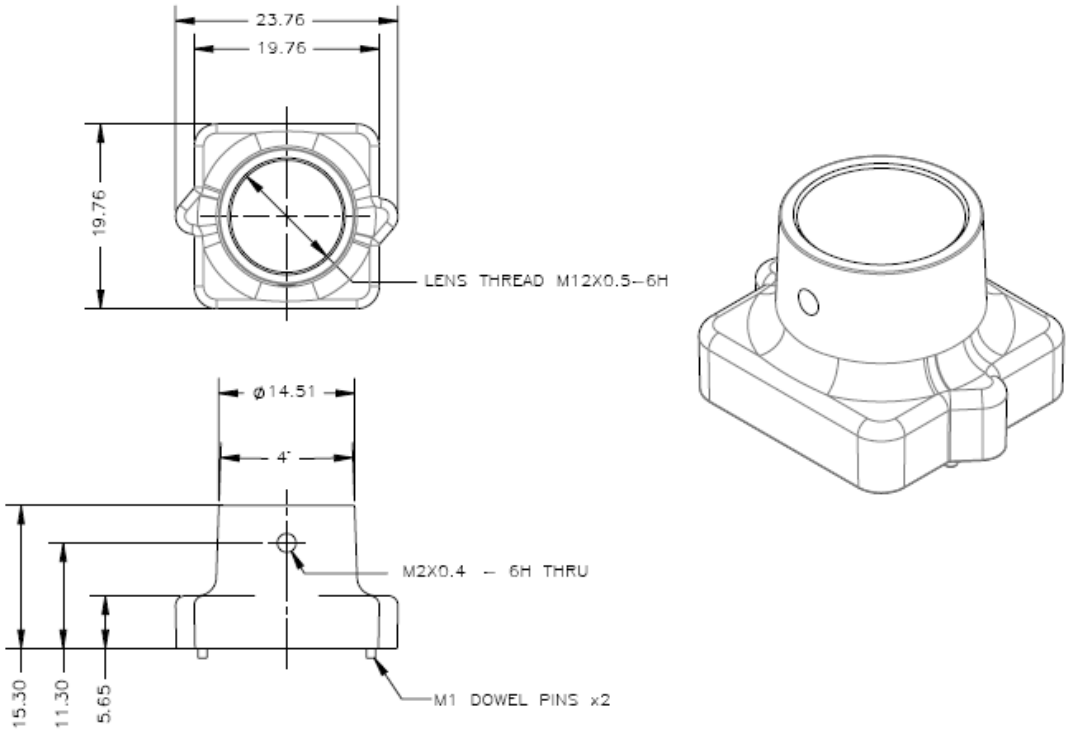
For board-level drawings of FMVU models, contact support@ptgrey.com.

2.1.4. Tripod Mount Adapter Dimensions



2.1.5. M12 Microlens Mount Dimensions

(Available separately for board-level camera models)



2.2. Lens Setup and Compatibility

The lens holder is compatible with CS-mount lenses. A 5 mm adapter (included) can be used to accommodate C-mount lenses. A 12 mm adapter can be used for mounting a microlens. Users with a board-level camera and microlens may mount a microlens holder to the board, instead of using an adapter. This solution is not recommended for case-enclosed cameras, as mounting the microlens holder requires opening the case and voiding the hardware warranty. Also, because the microlens holder has a smaller diameter than the CS-mount holder, there will be a gap between the microlens holder and the case.

Lenses and 12 mm microlens adapters are not included with individual cameras, but can be purchased separately from Point Grey Research. For more information, visit our Products Accessories web page.

To differentiate between C- and CS-mount lenses, consult the following article:

KB Article 98: ptgrey.com/support/kb/index.asp?a=4&q=98

2.3. 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.

2.4. Mounting

2.4.1. Top and Bottom Mounts

The FMVU-xx plastic case is equipped with four (4) M2 X 3.5 mounting holes on both the top and bottom faces of the case (8 holes total). These holes can be used to attach the camera directly to a custom mount or standard tripod. Because the case is plastic, plastic screws are required.

2.4.2. Front Mount

The *Firefly MV* board is equipped with four 2.1 PCB mounting holes that can be used to attach the camera directly to a custom fixture.

2.4.3. Tripod Mount Adapter

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

2.5. Infrared Cut-Off Filters

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

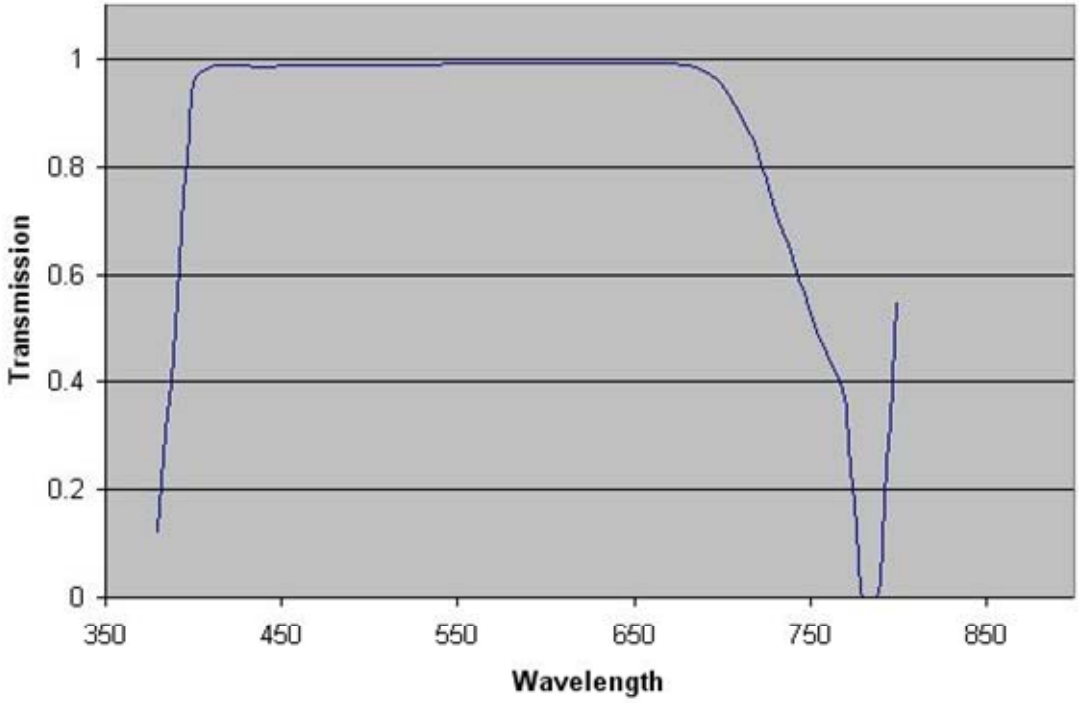


Figure 1: IR filter transmittance graph

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
345	Selecting a lens for your camera	www.ptgrey.com/support/kb/index.asp?a=4&q=345

2.6. IEEE-1394 Interface

2.6.1. Standard 6-pin IEEE-1394 Connector

Firefly MV FFMV models have a standard 6-pin IEEE-1394 connector (pin configuration shown below) that is used for data transmission, camera control and powering the camera.

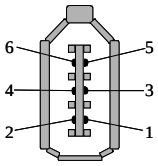


Figure 1: IEEE-1394 connector pin configuration

Pin	Function
1	Power Input (+8 to +32 VDC)
2	DC GND
3	TPB-
4	TPB+
5	TPA-
6	TPA+

Table 3: IEEE-1394 connector pin configuration

The signal on the Twisted Pair A is 1.0V DC. This voltage is then detected on the Twisted Pair B signal line; levels of 0.6 to 1.0V DC are used to determine when a device has been removed or added i.e. device attached >= 1.0V, device not attached <= 0.6V.

2.6.2. 8-pin Miniature Vertical IEEE-1394 Connector

Firefly MV part numbers 97-0010-06900 (mono) and 97-00100-07300 (color) are equipped with an 8-pin miniature IEEE-1394 vertical connector. For more information about this interface, see Knowledge Base Article 268.

2.7. USB 2.0 Interface

Firefly MV FMVU models have a USB 2.0 Mini-B vertical connector that is used for data transmission, camera control and powering the camera. For more detailed information, consult the USB 2.0 specification available from http://www.usb.org/developers/docs/.

The Firefly MV USB 2.0 interface is not backward compatible with a USB 1.1 interface. If the computer on which you want to operate a Point Grey USB camera does not have a built-in USB 2.0 host controller, you can install a USB 2.0 PCI host adapter card. For more information, refer to Knowledge Base Article 309: Using USB PCI 2.0 host adapter cards with USB cameras.

Related Knowledge Base Articles

ID	Title	URL
325	Differences between USB cameras and FireWire cameras	www.ptgrey.com/support/kb/index.asp?a=4&q=325

2.8. Cables

2.8.1. IEEE-1394 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

2.8.2. USB 2.0 Cables

The maximum cable length between any USB node (e.g. camera to USB, USB to hub, etc.) is 5.0m, as indicated by the USB specification. Standard, shielded twisted pair copper cables must be used. For more information, refer to the following FAQ on the usb.org website: http://www.usb.org/about/faq/ans5.

2.9. Host Adapter Card

FFMV-DEVKIT comes with a 2-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

2.10. Camera Power

2.10.1. Providing Power via the 1394 Interface

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 32V DC according to the IEEE 1394 standard. The power consumption is outlined in the Camera Specifications section.

Some systems - such as laptop computers or those with several FireWire devices connected - require an external power supply to power the camera. For 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

For information about providing power to cameras equipped with an 8-pin miniature IEEE-1394 vertical connector (part numbers 97-0010-06900 (mono) and 97-00100-07300 (color)), see Knowledge Base Article 268.

2.10.2. Providing Power Through the USB 2.0 Interface

The 5-pin USB 2.0 Mini-B vertical connector provides a power connection between the camera and the host computer. The ideal input voltage is 5V DC; however, the camera is designed to handle voltages between 4.75V and 5.25V DC according to the USB 2.0 standard. The power consumption is outlined in the Camera Specifications section.

2.10.3. Other Power Considerations

Some Point Grey cameras allow 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. Consult the Point Grey Digital Camera Register Reference for more information.

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

KB Article 295: http://www.ptgrey.com/support/kb/index.asp?a=4&q=295

2.11. General Purpose Input/Output (GPIO)

The *Firefly MV* has a 7-pin GPIO connector on the back of the case. The connector is made by JST (Mfg P/N: BM07B-SRSS-TB). The Development Kit contents include a pre-wired female connector; refer to the diagram below for wire color-coding. Additional female connectors (Mfg P/N: SHR-07V-S-B) can be purchased from Digikey (P/N: 455-1382-ND).

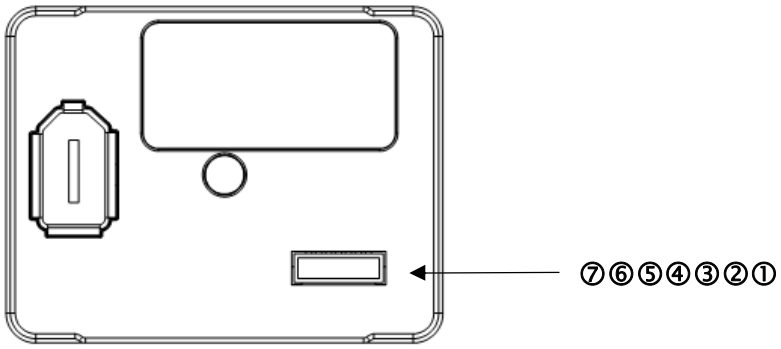


Figure 2: GPIO pin layout

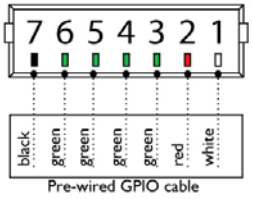
Diagram	Pin	GPIO	Function
	1	V_{EXT}	Power camera externally
	2	+3.3V	Power external circuitry up to a total of 150mA
	3	IO0	Input / Output (default Trigger_Src)
	4	IO1	Input / Output
	5	IO2	Input / Output / RS232 Transmit (TX)
	6	IO3	Input / Output / RS232 Receive (RX)
	7	GND	

Table 4: 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, see Section 3.8.2: Serial Communication Using GPIO.

2.11.1. GPIO Electrical Characteristics

The *Firefly MV* GPIO pins are bi-directional. When configured as outputs, they operate as open collector transistor logic. As inputs, the lines are internally pulled up to 3.3V.

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 1) allows the camera to be powered externally. On models with a IEEE-1394 interface, the voltage limit is 8-30V. On USB 2.0 models, the voltage limit is 4.75-5.25V.

The **+3.3V** pin (Pin 2) is fused at 200mA. External devices connected to Pin 1 should not attempt to pull anything greater than that.

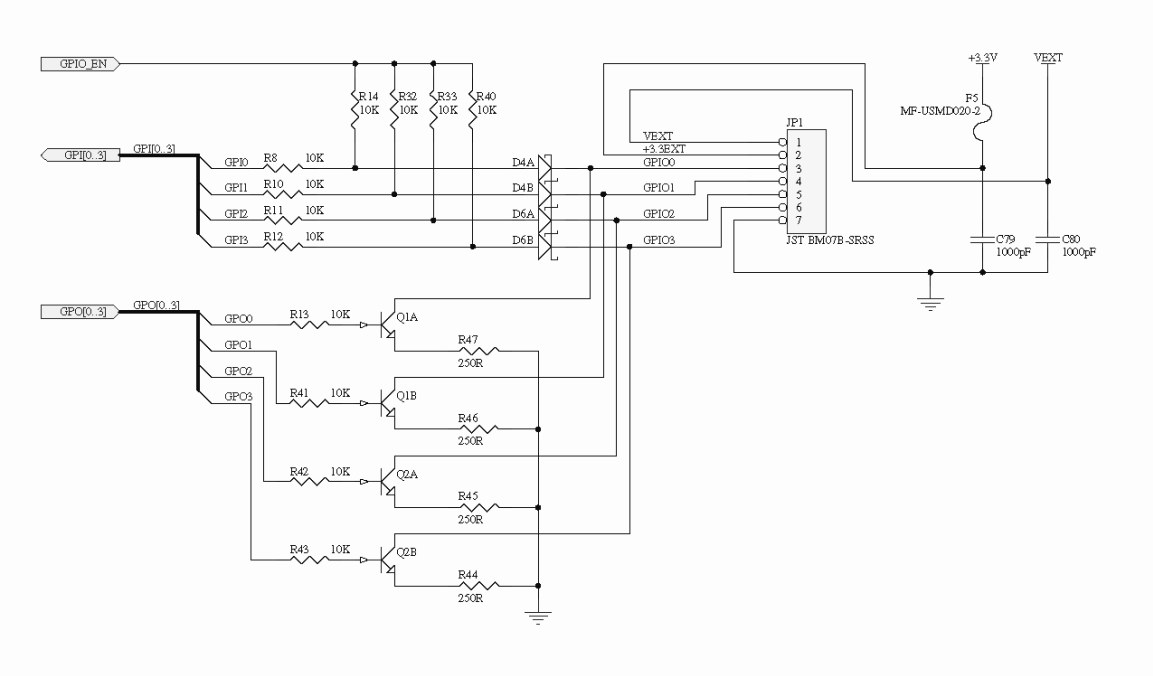


Figure 3: *Firefly MV* GPIO Circuit Diagram

2.12. Status Indicator LED

The LED on the back of the *Firefly MV* module provides the following general status messages:

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 or slow flashing on and off	Firmware updating, or possible camera problem

Table 5: Status indicator LED descriptions

3 Camera Operations and Features

Both the IEEE-1394 and USB 2.0 models of the *Firefly MV* comply with the *IIDC 1394-based Digital Camera Specification Version v1.31*.

To determine the specific IIDC v1.31 features implemented in a particular *Firefly MV* model, consult the following sections of the *Point Grey 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. The *Point Grey Digital Camera Register Reference* contains complete descriptions of the Camera Control Command Registers implemented on the *Firefly MV*.

The *Point Grey Digital Camera Register Reference* is included with the FlyCapture SDK and downloadable from www.ptgrey.com/support/downloads/.

3.1. General Camera Properties

The following section provides an overview of the different IIDC-compliant camera properties implemented by the *Firefly MV*. Definitions and the effects of these properties on an image can be found in the *Glossary* section and in various sections of this *Technical Reference* and in the *Point Grey Digital Camera Register Reference*.

The following property ranges apply to a lo-res *Firefly MV* at 640x480 resolution running at 15 FPS, and can change depending on the camera resolution and frame rate:

- Shutter: maximum values increase as frame rate decreases
- Pan: 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	Min	Max	Auto	On/Off	One Push	Absolute Mode	Defaults
Brightness	1	255	Y	N	N	N	Auto, On
Exposure	7	62	Y	Y	N	N	Auto, On
Gamma	0	1	N	Y	N	N	Off
Pan	0	112	Y	Y	N	N	Auto, On
Shutter	0.06 ms	33.19 ms	Y	N	N	Y	Auto, On
Gain	0 dB	12.04 dB	Y	N	N	Y	Auto, On
White Balance (COL)	1	1023	N	Y	N	N	On
Frame Rate	4.6 FPS	30.42 FPS	Y	Y	N	Y	Auto, On, 30 FPS

Table 6: General Camera Properties (FFMV-03M2, FMVU-03MT)

Property	Min	Max	Auto	On/Off	One Push	Absolute Mode	Defaults
Brightness	0	511	N	N	N	N	On
Exposure	1	1023	Y	Y	Y	Y	Auto, On
Gamma	512	4095	N	Y	N	N	Off
Shutter	0.12 ms	133 ms	Y	N	Y	Y	Auto, On
Gain	0 dB	18 dB	Y	N	Y	Y	Auto, On
White Balance (COL)	1	1023	N	Y	N	N	On
Frame Rate	1.36 FPS	60.09 FPS	Y	Y	N	Y	Auto, On, 15 FPS

Table 7: General Camera Properties (FMVU-13S2)

3.2. Data Flow

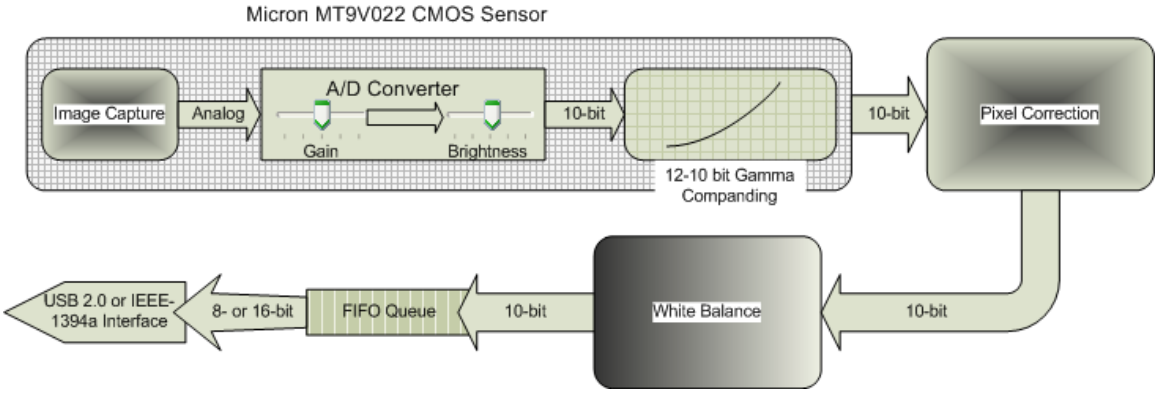


Figure 4: FFMV-03M2/FMVU-03MT Data Flow

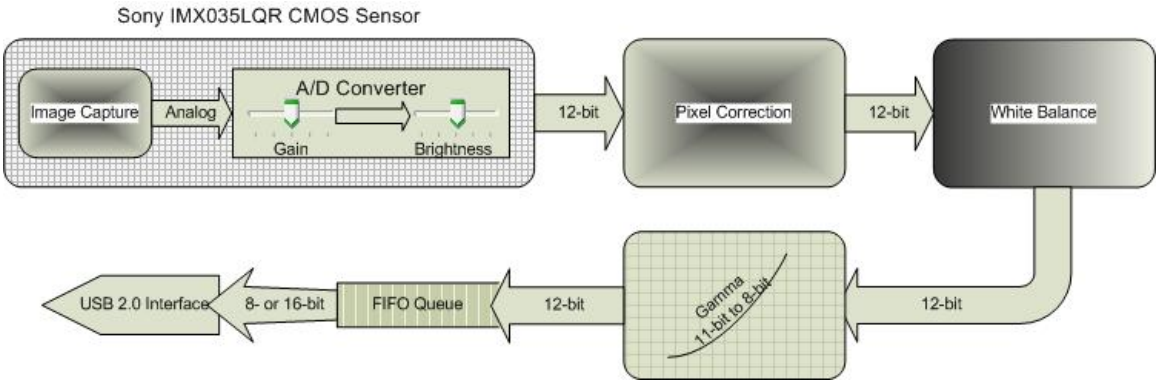


Figure 5: FMVU-13S2 Data Flow

Image Data Flow Step	Description
Sensor	Image capture, analog-to-digital conversion and gamma adjustment (FFMV-03M2/FMVU-03MT only) all take place on board the camera sensor.
Analog to Digital (A/D) Converter	The sensor's A/D Converter transforms pixel voltage into a 10- or 12-bit value, adjusting for gain and brightness in the process. Gain and brightness cannot be turned off.
Gamma	The *Firefly MV* supports gamma adjustment to reduce noise at low light levels. For more information, see Section 3.6.2 Lookup Table and Gamma. The gamma setting of the camera's default memory channel is OFF, and no correction occurs.
Pixel Correction	The camera firmware corrects any blemish pixels identified during manufacturing quality assurance by applying the average value of neighboring pixels. For more information, see Knowledge Base Article 314.
White Balance	In color models, color intensities can be adjusted manually to achieve more correct balance. The white balance setting of the camera's default memory channel is ON. If not ON, no white balance correction occurs.
FIFO Queue	The final output of image data is controlled in a first-in, first-out (FIFO) queue.
1394a or USB 2.0 Interface	Depending on your camera's interface, data is transferred at the following rates: • 480 Mbit/s via a 5-pin Mini-B USB 2.0 port • 400 Mbit/s via a 6-pin IEEE-1394a port

3.3. Standard Data Formats, Modes and Frame Rates

This section lists the different video formats, modes and frame rates that are supported by the Chameleon. 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

Models: FFMV-03M2C FFMV-03M2M FMVU-03MTC FMVU-03MTM FMVU-13S2C

Modes	7.5fps	15fps	30fps*	60fps*
640x480 Y8	● ● ● ● ●	● ● ● ● ●	● ● ● ● ●	● ● ● ● ●
640x480 Y16	● ● ● ● ●	● ● ● ● ●	● ● ● ●	
1280x960 Y8	●	●		
1280x960 Y16	●			

*B/W output only. Color data is removed due to pixel binning.

Table 8: Supported video formats, modes and frame rates

3.4. Frame Rates and Camera Bandwidth

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

3.4.1. Maximum Number of Cameras on a Single Bus—1394

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 1394a 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). Similar adapters based on the Lucent/Agere chipset support up to 8 DMA 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 1394a bus is 400Mbits/sec (5120Bytes/packet - 8000 cycles/sec). The usable bandwidth as defined by the 1394a Trade Association and enforced by the Microsoft Windows 1394 driver stack (1394bus.sys, ohci1394.sys, etc.) is approximately 80% or 40MBytes/sec (4096Bytes/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 4915Bytes/packet.

- The 1394a 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 of your camera's Technical Reference or Getting Started manual to determine the amount of power required to operate the cameras effectively.

3.4.2. Maximum Number of Cameras on a Single Bus—USB 2.0

A single USB port generally constitutes a single "bus". The USB standard allows for 127 devices (including up to five levels of hub devices) to be connected to a single bus. In practice, however, this limit may be further defined by the following considerations:

- Adequate power supply. The *Firefly MV USB* requires 5 volts (V) of power to operate effectively. While a standard, non-powered bus provides 500 milliamps (mA) of power at 5V, an internal, bus-powered hub provides only 400mA. Externally-powered hubs provide 500mA per port.
- Adequate bandwidth. The USB 2.0 bandwidth capacity is 480 megabits per second (Mbit/s). Depending on the operating configuration of the cameras and other devices, this bandwidth must be shared on the system.
- Adequate CPU cycles. There must be enough CPU cycles to allow for the USB 2.0 polling I/O to operate normally. If polling is constrained, the camera's FIFO buffer may overflow, resulting in dropped frames.

Point Grey does not support the use of multiple USB 2.0 cameras streaming simultaneously on the same computer. There has been no rigorous qualification of the ability of various hardware platforms, operating systems, software, and drivers to handle multiple USB 2.0 image streams. Therefore, questions or troubleshooting of these issues cannot be addressed. Wherever possible, Point Grey FireWire cameras should be used for applications that require multiple cameras running simultaneously on the same computer.

3.4.3. 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 bandwidth, and can be roughly approximated using the following general formula (assuming all cameras are at the same resolution):

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

Example:
To calculate the approximate frames per second available to two 1394a, 640x480 *Firefly MVs* that are in 8-bit mode, you would calculate:

Frames_per_second = (40MB/s / (640*480*1byte/pixel)) / 2
= (40MB/s / 0.29MB/total_frames) / 2
= 138 FPS / 2
= 69 FPS

The calculation above is only a rough estimate. The IEEE-1394 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 *Point Grey Digital Camera Register Reference*.

For example, a single *Firefly MV* in 640x480 Y16 mode running at 15 FPS is sending 640 pixels per packet. Each pixel consists of 16 bits, or 2 bytes, of data. Therefore, the camera is sending 640*2 = 1280Bpp of data. The maximum bandwidth of the 1394a bus as discussed above is 4096Bpp, so it would be possible for 4096/1280 = 3 (rounded down) *Firefly MV*'s to run in 640x480 Y16 mode at 15 FPS on the same 1394a bus.

3.4.4. Problems Maximizing Frame Rates

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

Example:
According to the formula in the section *Calculating Maximum Possible Frame Rate* it is possible to run four 640x480 cameras in Y8 (8-bit) mode at 30 FPS. However, when attempting to do this via the FlyCap demo program *Format and Frame Rate* controls, starting the fourth camera at 30 FPS often results in a "bandwidth exceeded" error.

The workaround to this problem is to circumvent the Windows bandwidth restrictions by directly manipulating the camera's CURRENT_FRAME_RATE register 600h. In the example above, start three instances of the FlyCap demo program, with each camera running at 30 FPS. Start the fourth camera up at 15 FPS, then access register 600h and set the register to 0x80000000 (FrameRate_4: 30 FPS).

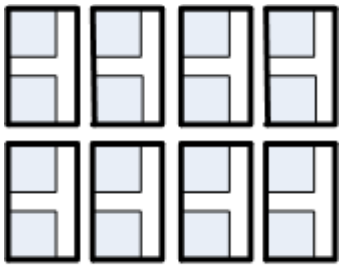
3.5. Customizable Data Formats and Modes

The *Firefly MV* implements IIDC Format_7 customizable video modes (see the *Customizable Formats and Modes* section for camera-specific information) that allow for faster frame rates based on selecting a specific region of interest (ROI) of the image or by configuring the camera to aggregate pixel values using a process known as "binning".

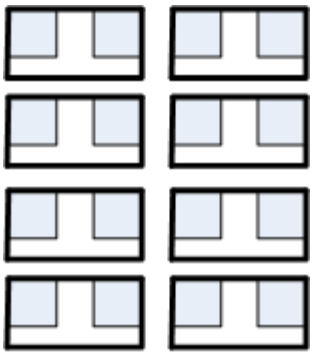
The table below outlines the Format_7 custom image modes that are supported by the *Firefly MV*. The implementation of these modes and the frame rates that are possible are not specified by the IIDC, and are subject to change across firmware versions.

All Format_7 modes allow specifying a region of interest (sub-window) for transmission. Additionally, Mode_1 and Mode_2 implement pixel binning. Binning is performed directly on the CMOS sensor chip. The FMVU-13S2C model supports binning of raw Bayer-tiled data. As a result, color data is maintained. Color binning is not supported on the FMVU-03MTC or FFMV-03M2C. Color data is not maintained when operating these models in pixel binning mode.

Mode_1 implements a combination of 2X vertical and 2X horizontal binning, resulting in images that are half the resolution of the original image, both in height and width. Mode_2 implements vertical binning only, resulting in a half-height resolution. The figures below illustrate how binning works. 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.



2X Vertical Binning



2X Horizontal Binning

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.

The FMVU-13S2 supports only two ROI configurations in Format_7 mode: full-size and 640x480, which is obtained from the sensor's 'center cut-out' feature. The center cut-out ROI can be dynamically moved within the larger pixel array.

Related Knowledge Base Articles

ID	Title	URL
163	What are the differences between pixel binning and region of interest custom image modes?	www.ptgrey.com/support/kb/index.asp?a=4&q=163

FFMV-03M2C & FMVU-03MTC

Mode	Pixel Format	Unit Size (H,V)	640x480 FPS	320 x 240 FPS	160 x 120 FPS
0	Raw8	4,4	61	112	193
0	Raw16	4,4	49	112	193
1	Mono8	2,2	-	122	224
1	Mono16	2,2	-	122	224
2	Mono8	4,2	-	122	224
2	Mono16	4,2	-	122	224

Table 9: Partial image (Format 7) video formats, modes and frame rates for FFMV-03M2C and FMVU-03MTC

FMVU-13S2C

Mode	Pixel Format	Unit Size (H,V)	1328x1048 FPS	664x524 FPS	640x480 FPS
0	Raw8	4,4	23		60
0	Raw16	4,4	50		12
1	Raw8	4,4		60	
1	Raw16	4,4		47	

Table 10: Partial image (Format 7) video formats, modes and frame rates for FMVU-13S2C

3.5.1. 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:

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

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 640x480, pixel format of Mono16 (2 bytes per pixel), and 4088 bytes per packet, the calculation would be as follows:

FPS = 1 / ((640*480*2 / 4088) * 0.000125)
FPS = 53

3.6. Image Acquisition

3.6.1. Camera Power

The FFMV-03M2M/C and FMVU-03MTM/C models allow 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.

3.6.2. Shutter

The *Firefly MV* supports automatic and manual control of the CMOS shutter time. Refer to Section 1.2 for ranges by model. Shutter times are scaled by the divider of the basic frame rate. For example, dividing the frame rate by two (e.g. 15 FPS to 7.5 FPS) causes the maximum shutter time to double (e.g. 66ms to 133ms).

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

The terms "integration" and "exposure" are often used interchangeably with "shutter time".

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 *Firefly MV* 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.

For an explanation of the differences between global shutter (FFMV-03M2 & FMVU-03MT) and rolling shutter (FMVU-13S2), refer to the following knowledge base article:

Related Knowledge Base Articles

ID	Title	URL
115	Key differences between rolling shutter and frame (global) shutter	www.ptgrey.com/support/kb/index.asp?a=4&q=115

3.6.3. Gain

The *Firefly MV* supports automatic and manual 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. Refer to Section 1.2 for ranges by model.

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

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

3.6.4. 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, gain and/or iris.
On Manual AE	The camera automatically modifies shutter, gain and/or iris 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 or 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.

3.6.5. Extended Shutter Times

The maximum shutter time for the *Firefly MV* 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, the *Max_Value* of the ABS_VAL_SHUTTER register increases.

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
FFMV-03M2M/C FMVU-03MTM/C	640x480 Y8, 60 FPS	0.03	64	
	640x480 Y8, 30 FPS	0.06	128	
	640x480 Y8, 15 FPS	0.12	256	
	640x480 Y8, 7.5 FPS	0.25	512	
FMVU-13S2C	640x480 Y8, 60 FPS	0.04	2004	
	640x480 Y8, 30 FPS	0.07	4011	
	640x480 Y8, 15 FPS	0.13	8025	
	640x480 Y8, 7.5 FPS	0.25	16053	

Table 11: Extended shutter minimum and maximum times

Related Knowledge Base Articles

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

3.6.6. Automatic Inter-Camera Synchronization

3.6.6.1. Synchronization of 1394 Cameras

Synchronizing multiple FFMV cameras is subject to the following limitations:

1) The cameras must be using firmware version 0.0.0.11 or later.

2) The cameras must be running in a standard image capture mode (non-Format_7).

3) The cameras must be running at 30 or 60 FPS.

Synchronizing multiple FFMV cameras across buses can be configured without any special conditions beginning with firmware version 0.9.2.5.

To upgrade camera firmware, visit http://www.ptgrey.com/support/downloads/index.asp.

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.

MultiSync™ software is compatible with the *Firefly MV* as of Firmware version 0.0.0.11

Related Knowledge Base Articles

ID	Title	URL
112	Synchronizing Point Grey cameras across multiple PCs	www.ptgrey.com/support/kb/index.asp?a=4&q=112

3.6.6.2. Synchronization of USB Cameras

Point Grey does not support synchronizing multiple USB cameras on the same bus. For more information, see Section 3.4.2: Maximum Number of Cameras on a Single Bus—USB 2.0.

3.6.7. Frame Rate Control

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

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).

3.6.8. Y16 (16-bit Mono) Image Acquisition

The *Firefly MV* can output Y16 (16 bit-per-pixel) mono images. However, the camera uses a 10-bit A/D converter, depending on model (see the *Analog-to-Digital Converter* section). Therefore, only 10 bits of useable data are 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 *Point Grey Digital Camera Register Reference* for more information.

The PGM file format can be used to correctly save 16-bit images. However, an appropriate photo manipulation/display application must be used to correctly display true 16-bit images. XV, ImageJ or Adobe Photoshop are suggested solutions.

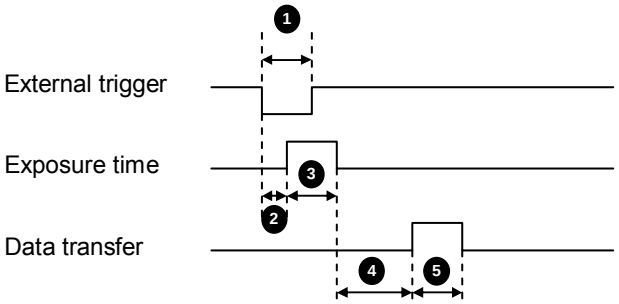
3.6.9. Asynchronous (External) Trigger Modes

The *Firefly MV* supports 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 and 3. These modes and their operation are described in greater detail in the *Point Grey Digital Camera Register Reference*.

The Micron sensor on FFMV-03M2 and FMVU-03MT models implements different gain registers between isochronous and asynchronous modes. Although the gain setting on the camera remains the same, switching from free-running mode to trigger mode may result in darker images and require an automatic or manual re-adjustment of the gain setting.

3.6.9.1. External Trigger Timing

The time from the external trigger going low to the integration time is shown below:



	FFMV-03M2/FMVU-03MT	FMVU-13S2
1	Min 1µs	Min 1µs
2	less than 10µs	Varies according to shutter speed; approximately the difference between frame rate and shutter speed.
3	Exposure time	Exposure time
4	1 ms	1 -2 horizontal line scans; horizontal line frequency can be read from register 0x1AF4.
5	30 ms (30 FPS)	30 ms (30 FPS)

Figure 6: *Firefly MV* external trigger timing characteristics

3.6.9.2. Ensuring Trigger is Armed

It is possible for the *Firefly MV* 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 CMOS.

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

Once 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 IIDC 1.31 Trigger_Mode_0	www.ptgrey.com/support/kb/index.asp?a=4&q=221

3.6.9.3. Minimum Trigger Pulse Length

The minimum trigger pulse length that the camera will respond to is 16 ticks of the current pixel clock. The pixel clock frequency can be read from the floating point PIXEL_CLOCK_FREQ register 0x1AF0.

3.7. Image Processing

3.7.1. Color and Greyscale Conversion

The color *Firefly MV* model provides raw Bayer data for users to apply their own color conversion algorithm or one of the FlyCapture library algorithms. Images should be acquired using one of the Format_7 video modes that support Raw8 or Raw16 pixel encoding, or non-Format_7 Y8 / Y16 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. 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 Point Grey 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

3.7.2. Gamma

Sensor manufacturers strive to make the transfer characteristics inherently linear, which means that as the number of photons hitting the imaging sensor increases, the resulting image intensity increases will be linear. To augment this linearity, the FFMV-03M2M/C and FMVU-03MTM/C support 12-10 bit gamma companding, which produces a non-linear response, and can reduce noise at low light levels. Gamma is OFF (0) by default. To enable companding, set gamma to 1.

The FMVU-13S2C supports gamma functionality in conjunction with an 11-bit input lookup table that produces 8-bit output. Gamma can be controlled using the GAMMA register 0x818. By default, Gamma is OFF and has a value of 1.0, which yields a linear response. Direct manipulation of the lookup table is not supported.

Related Knowledge Base Articles

ID	Title	URL
280	High dynamic range (HDR) mode on Firefly MV	www.ptgrey.com/support/kb/index.asp?a=4&q=280

3.7.3. White Balance

The *Firefly MV* 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.

3.7.4. Image Flip / Mirror

The FFMV-03M2M/C and FMVU-03MTM/C models support horizontal image mirroring. The mirror image operation is performed on the camera using an on-board frame buffer, and is controlled using the IMAGE_DATA_FORMAT register 0x1048, which is described in detail in the *Point Grey Digital Camera Register Reference*.

3.7.5. Embedded Image Information

The *Firefly MV* has a feature that allows image timing and camera settings information to be embedded in the first several pixels of each image. This feature is controlled using the

FRAME_INFO register 0x12F8, which is described in detail in the *Point Grey Digital Camera Register Reference*.

The following table indicates which embedded image properties are supported by the *Firefly MV*, by model:

Embedded Image Property	FFMV-03M2 FMVU-03MT	FMVU-13S2
Timestamp	Y	Y
GPIO Pin State	Y	Y
Strobe Pattern	Y	N
Exposure	N	Y

3.8. Camera and Device Control

3.8.1. Programmable Strobe Output

The *Firefly MV* 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 *Firefly MV* 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 IIDC 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

3.8.2. Serial Communication Using GPIO

Beginning with firmware version 0.9.2.6, the *Firefly MV* is capable of serial communications at baud rates up to 115.2Kbps via the on-board serial port built into the camera's GPIO connector. The serial port uses TTL digital logic levels. If RS-232 signal levels are required, 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

3.8.3. Memory Channel Storage of Camera Settings

The *Firefly MV* 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 *Firefly MV* 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 Appendix B: Memory Channel Registers, for a full listing of all registers saved.

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

Related Knowledge Base Articles

ID	Title	URL
290	Using memory channels to configure default start-up settings	http://www.ptgrey.com/support/kb/index.asp?a=4&q=290

3.8.4. Camera Upgrades

The firmware on the *Firefly MV* 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: 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.
IIDC	Abbreviation for Instrumention and Industrial Digital Camera. The *IIDC 1394-based Digital Camera Specification* 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 IIDC 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 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: Technical Support Resources

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

Creating a Customer Login Account

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

Knowledge Base

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

Product Downloads

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

Contacting Technical Support

Before contacting Technical Support, have you:

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

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

Appendix D: Contacting Point Grey Research

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

Email:

For all general questions about Point Grey Research please contact us at info@ptgrey.com.

For technical support (existing customers only) contact us at http://www.ptgrey.com/support/contact/.

Knowledge Base:

Find answers to commonly asked questions in our knowledge base at http://www.ptgrey.com/support/kb/.

Downloads:

Users can download the latest manuals and software from http://www.ptgrey.com/support/downloads/

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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 E: Revision History

Revision	Date	Notes
1.1	July 9, 2009	• Added RS-232 serial port functionality. See Section 2.11: General Purpose Input/Output (GPIO) and Section 3.8.2: Serial Communication Using GPIO • Provided clearer GPIO circuit diagram in Section 2.11.1: GPIO Electrical Characteristics.
1.2	August 27, 2009	• Added link to Knowledge Base Article 295 in Section 2.10.3: Other Power Considerations. • Clarified in Section 3.5 that the Format_7 center cut-out ROI of the FMVU-13S2 can be dynamically moved within the larger pixel array. • Updates per the following Product Change Notification (PCN) #'s: o 2009001A: Discontinuation Notice for Firefly MV Board-Level IEEE 1394a Models with CS Lens Mount o 2009002A: Discontinuation Notice for Firefly MV Board-Level IEEE 1394a Models with M12 Microlens Mount o 2009003A: Discontinuation Notice for Firefly MV IEEE 1394a Development Accessory Kit • Section 3.5 Customizable Data Formats and Modes: Removed Mono8/16 formats from Format_7 Mode 0. These formats are no longer supported. • Section 3.6.9 Asynchronous (External) Trigger Modes: Added note about re-adjusting gain after switching between free-running and trigger mode on Micron sensor models.
1.3	April 29, 2010	• Section 3.5.1 Calculating Format_7 Frame Rates: Updated equation. • Added Section 2.1.5 M12 Microlens Mount Dimensions • Section 3.3 Standard Data Formats, Modes and Frame Rates Clarified that 30 and 60 FPS are achieved through pixel binning, with no color output. • Section 1.2.3 FMVU-13S2C Specifications: Changed maximum gain setting to 18 dB.

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