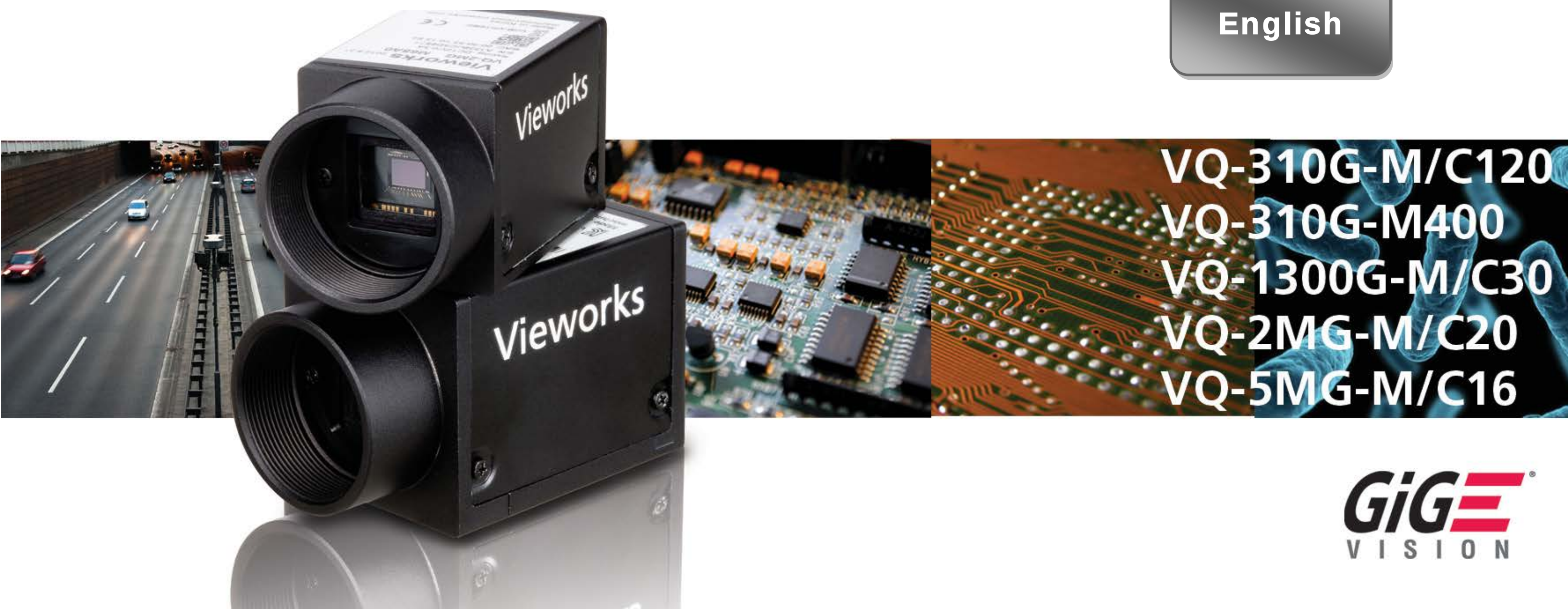
User Manual

English



GiGE VISION

vieworks

Revision History

Version	Date	Description
1.0	2013-06-30	Initial Release
1.1	2014-01-02	Added VQ-310G-400
1.2	2014-03-14	• Added VQ-2MG-20 • Modified descriptions for Status LED on VQ-310G-M400

Contents

1 Precautions

General

CAUTION

- Do not drop, disassemble, repair or alter the device. Doing so may damage the camera electronics and cause an electric shock.
- Do not let children touch the device without supervision.
- Stop using the device and contact the nearest dealer or manufacturer for technical assistance if liquid such as water, drinks or chemicals gets into the device.
- Do not touch the device with wet hands. Doing so may cause an electric shock.
- Do not store the device at a higher temperature. In addition, maintain the ambient temperature in a range of 0℃ to 40℃ during operation. Otherwise the device may be damaged by excessively high temperatures.

Installation and Maintenance

CAUTION

- Do not install in dusty or dirty areas - or near an air conditioner or heater to reduce the risk of damage to the device.
- Avoid installing and operating in an extreme environment where vibration, heat, humidity, dust, strong magnetic fields, explosive/corrosive mists or gases are present.
- Do not apply excessive vibration and shock to the device. This may damage the device.
- Avoid direct exposure to a high intensity light source. This may damage the image sensor.
- Do not install the device under unstable lighting conditions. Severe lighting change will affect the quality of the image produced by the device.
- Do not use solvents or thinners to clean the surface of the device. This can damage the surface finish.

Power Supply

CAUTION

- Applying incorrect power can damage the camera. If the voltage applied to the camera is greater or less than the camera's nominal voltage, the camera may be damaged or operate erratically. Please refer to 5.2 Specifications for the camera's nominal voltage.
  ※ Vieworks Co., Ltd. does NOT provide power supplies with the devices.
- Make sure the power is turned off before connecting the power cord to the camera. Otherwise, damage to the camera may result.

2 Warranty

Do not open the housing of the camera. The warranty becomes void if the housing is opened.
For information about the warranty, please contact your local dealer or factory representative.

3 Compliance & Certifications

3.1 FCC Compliance

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 expenses.

3.2 CE : DoC

EMC Directive 2004/108/EC.
Testing Standard EN 55022:2006+A1:2007, EN 55024:1998+A1:2001+A2:2003
Class A

3.3 KC

KCC Statement

Type	Description
Class A (Broadcasting Communication Device for Office Use)	This device obtained EMC registration for office use (Class A), and may be used in places other than home. Sellers and/or users need to take note of this.

4 Package Components

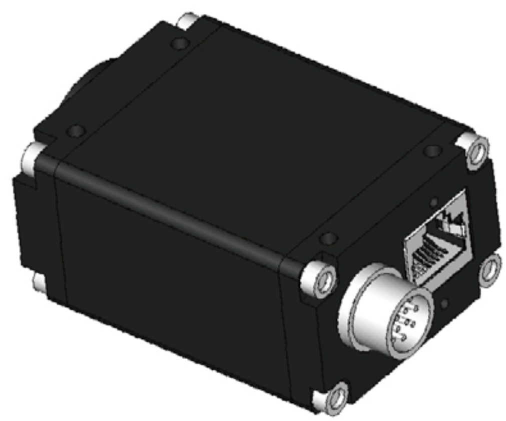
Package Components

VQ-310G-120, VQ-1300G-30, VQ-2MG-20 CS mount

VQ-310G-120, VQ-1300G-30, VQ-2MG-20 C mount

VQ-5MG-16 C mount

VQ-310G-M400 CS mount



VQ Camera

Mount Plate (Optional, Except VQ-310G-M400)

5 Product Specifications

5.1 Model

VQ series is a progressive scan, high performance industrial area scan camera. All features of VQ series can be programmed and easily updated in the field through Gigabit Ethernet interface. The camera is developed based on GenICam standard. The image processing and controls of VQ series are based on embedded FPGA with 32 bit RISC microprocessor.

Main Features

- ×1, ×2, ×3, ×4 Horizontal and Vertical Binning (Except VQ-310G-M400)
- Stream Hold
- Inter-Packet Delay
- Camera Image Memory: 64MB
- Field Upgradable Firmware
- Pixel Defect Correction (Binning Mode: 2×2, 4×4)
- Electronic Shutter – Global Shutter
- Output Pixel Format – 8/10/12 bit
- Gigabit Ethernet Interface
- Temperature Monitor

5.2 Specifications

VQ series technical specifications are as follows.

VQ Series		VQ-310G-120	VQ-1300G-30	VQ-2MG-20
Active Image (H × V)		656 × 488	1296 × 960	1624 × 1232
Sensor Type		SONY ICX424 AL/AQ	SONY ICX445 AL/AQ	SONY ICX274 AL/AQ
Pixel Size		7.4 ㎛ × 7.4 ㎛	3.75 ㎛ × 3.75 ㎛	4.4 ㎛ × 4.4 ㎛
Optical Size		1/3”	1/3”	1/1.8”
Output Format	Mono	Mono 8, Mono 10, Mono 12, Mono 10 Packed, Mono 12 Packed		
	Color	Bayer BG 8, Bayer BG 12, Bayer BG 12Packed YUV422 Packed, YUV422 (YUYV) Packed		
Camera Interface		Gigabit Ethernet		
Electronic Shutter		Global Shutter		
Max. Frame Rate at Full Resolution		120 fps	30 fps	20 fps
Dynamic Range		> 52 ㏈		> 48 ㏈
Shutter Speed (10 ㎲ step)		22 ㎲~ 7 s	9 ㎲~ 7 s	30 ㎲~ 7 s
Partial Scan (Max. Speed)		451 fps at 60 Lines	118 fps at 120 Lines	90 fps at 154 Lines
Binning		×1, ×2, ×3, ×4 (Horizontal and Vertical Independent)		
Lookup Table		G=1.0, User Defined Lookup Table (LUT)		
Black Level		Adjustable (0 ~ 128 LSB at 12 bit, 256 steps)		
Analog Gain		×1 ~ ×40 (0 ~ 32 ㏈)		
Exposure Mode		Timed Exposure, Trigger Width Exposure, Double Exposure		
External Trigger		3.3 V ~ 24.0 V, 10 ㎃, Asynchronous, optically isolated		
Software Trigger		Asynchronous, Programmable via Camera API		
Camera Image Memory		64 MB		
Auto Control		Auto Gain, Auto Exposure, Auto White Balance		
API SDK		Vieworks Imaging Solution 6.X		
Lens Mount		C-mount or CS-mount		
Power		Power over Ethernet(802.3af) or 8 ~ 38 V DC		
Environmental		Operating: 0℃ ~ 40℃, Storage : -40℃ ~ 70℃		
Mechanical		29 ㎜ × 29 ㎜ × 56.4 ㎜ 91g (with C-mount) 29 ㎜ × 29 ㎜ × 51.4 ㎜ 86g (with CS-mount)		

Table 5.1 Specifications of VQ series (VQ-310G-120/1300G-30/2MG-20)

VQ Series		VQ-5MG-16
Active Image (H × V)		2448 × 2056
Sensor Type		SONY ICX625 AL/AQ
Pixel Size		3.45 ㎛ × 3.45 ㎛
Optical Size		2/3"
Output Format	Mono	Mono 8, Mono 10, Mono 10 packed, Mono 12, Mono 12 packed
	Color	Bayer RG8, Bayer RG12, Bayer RG12 packed
Camera Interface		Gigabit Ethernet
Electronic Shutter		Global Shutter
Max. Frame Rate at Full Resolution		16 fps
Dynamic Range		> 52 ㏈
Shutter Speed (10 ㎲ step)		39 ㎲~ 7 s
Partial Scan (Max. Speed)		41 fps at 256 Lines
Binning		×1, ×2, ×3, ×4 (Horizontal and Vertical Independent)
Lookup Table		N/A
Black Level		Adjustable (0 ~ 128 LSB at 12 bit, 256 steps)
Analog Gain		×1 ~ ×40 (0 ~ 32 ㏈)
Exposure Mode		Timed Exposure, Trigger Width Exposure, Double Exposure
External Trigger		3.3 V ~ 24.0 V, 10 ㎃, Asynchronous, optically isolated
Software Trigger		Asynchronous, Programmable via Camera API
Camera Image Memory		64 MB
Auto Control		Auto White Balance
API SDK		Vieworks Imaging Solution 6.X
Lens Mount		C-mount or CS-mount
Power		Power over Ethernet (802.3af) or 8 ~ 38 V DC
Environmental		Operating: 0℃ ~ 40℃, Storage : -40℃ ~ 70℃
Mechanical		35×35×59.7 ㎜ 83g (with C-mount)
		35×35×54.7 ㎜ 83g (With CS-mount)

Table 5.2 Specifications of VQ series (VQ-5MG-16)

VQ Series	VQ-310G-M400
Active Image (H × V)	640 × 480
Sensor Type	CMOSIS CMV 300
Pixel Size	7.4 ㎛ × 7.4 ㎛
Optical Size	1/3”
Output Format	Mono 8, Mono 10, Mono 10 packed, Mono 12, Mono 12 packed
Camera Interface	Gigabit Ethernet
Electronic Shutter	Global Shutter
Max. Frame Rate at Full Resolution	400 fps
Dynamic Range	> 56 ㏈
Shutter Speed (10 ㎲ step)	65 ㎲~ 7 s
Partial Scan (Max. Speed)	7900 fps at 2 Lines
Binning	N/A
Lookup Table	G=1.0, User Defined Lookup Table (LUT)
Black Level	Adjustable (0 ~ 256 LSB at 12 bit, 256 steps)
Analog Gain	×1, ×1.25, ×1.5, ×1.75, ×2, ×2.5, ×3, ×3.5
Exposure Mode	Timed Exposure, Trigger Width Exposure
External Trigger	3.3 V ~ 24.0 V, 10 ㎃, Asynchronous, optically isolated
Software Trigger	Asynchronous, Programmable via Camera API
Camera Image Memory	64 MB
Auto Control	Auto Gain, Auto Exposure
API SDK	Vieworks Imaging Solution 6.X
Lens Mount	CS-mount
Power	10 ~ 14 V DC (Max. 3W)
Environmental	Operating: -10℃ ~ 55℃, Storage : -40℃ ~ 70℃
Mechanical	44×29×60 ㎜ 100g (With CS-mount)

Table 5.3 Specifications of VQ series (VQ-310G-M400)

5.3 Camera Block Diagram (Except VQ-310G-M400)

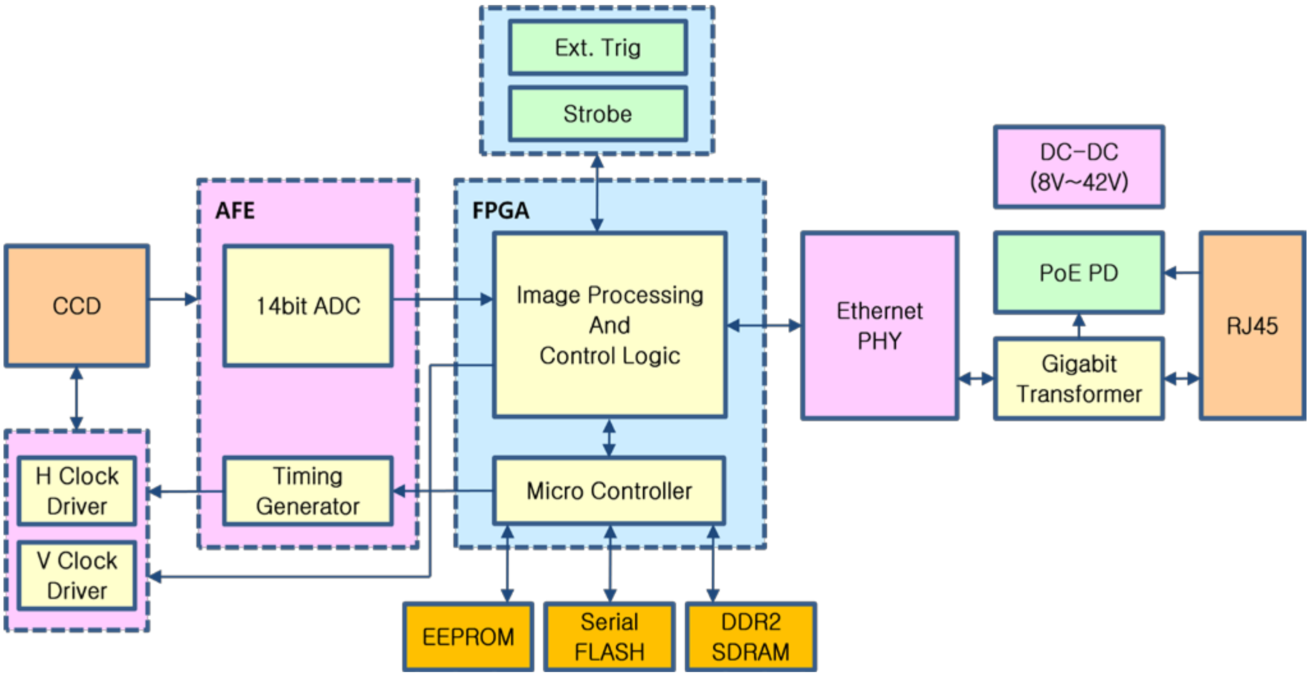


Figure 5.1 Camera Block Diagram (Except VQ-310G-M400)

All controls and data processing of the camera are carried out in one FPGA chip. The FPGA generally consists of a 32 bit RICS Micro-Controller and Processing & Control Logic.

The Micro-Controller receives commands from the user through the Gigabit Ethernet interface and then processes them. The FPGA controls the Timing Generators (TGs) and the Analog Front End (AFE) chips where the TGs generate CCD control signals and AFE chips convert analog CCD output to digital values to be accepted by the Processing & Control Logic. The Processing & Control Logic processes the image data received from AFE and then transmits data through the Gigabit Ethernet interface. And also, the Processing & Control Logic controls the trigger input and output signal which are sensitive to time. Furthermore, DDR2 for operating Micro-Controller, for used as Gigabit Ethernet frame buffer and for used as a frame buffer to process images, Gigabit Ethernet Controller and Flash memory for saving system codes and defect coordinates are installed outside FPGA.

5.4 Camera Block Diagram (VQ-310G-M400)

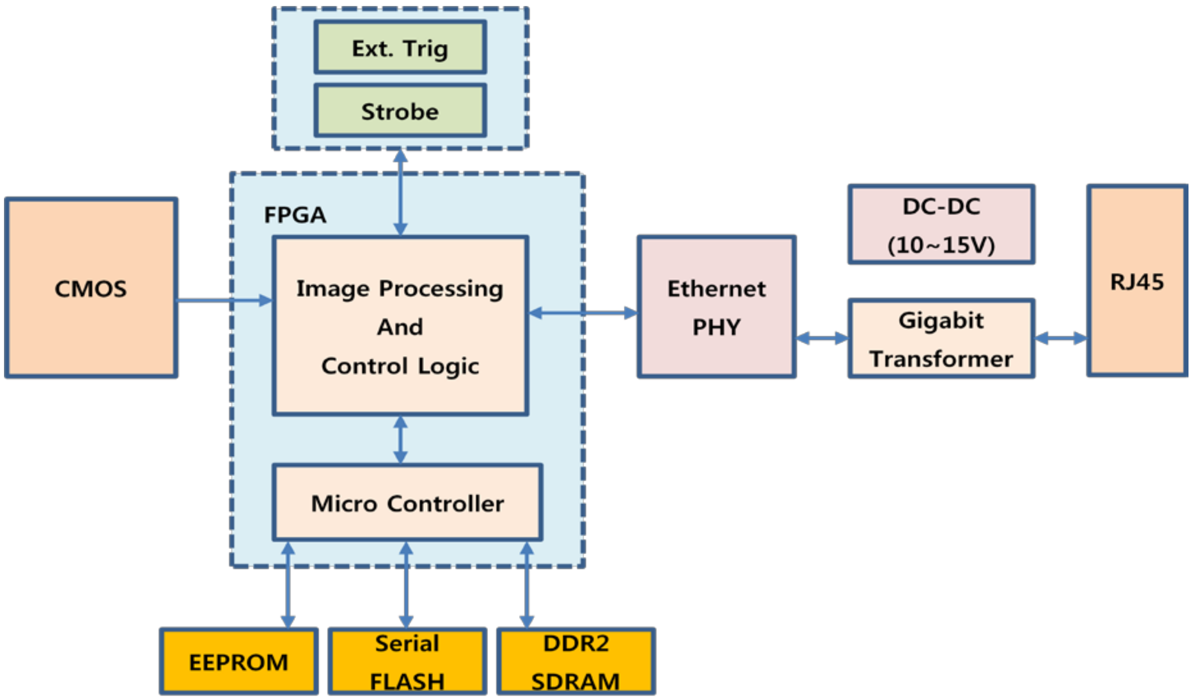


Figure 5.2 Camera Block Diagram (VQ-310G-M400)

All controls and data processing of the camera are carried out in one FPGA chip. The FPGA generally consists of a 32 bit RICS Micro-Controller and Processing & Control Logic.

The Micro-Controller receives commands from the user through the Gigabit Ethernet interface and then processes them.

The Processing & Control Logic processes the image data received from the CMOS sensor and then transmits data through the Gigabit Ethernet interface. And also, the Processing & Control Logic controls the trigger inputs and strobe outputs which are sensitive to time. Furthermore, Flash and DDR2 SDRAM are installed outside FPGA. The Flash contains the firmware that operates the Micro-Controller and DDR2 SDRAM is used for frame buffer to process images.

5.5 Sensor Information

5.5.1 Mono Camera Spectral Response

The following graphs show the spectral response for VQ series monochrome cameras.

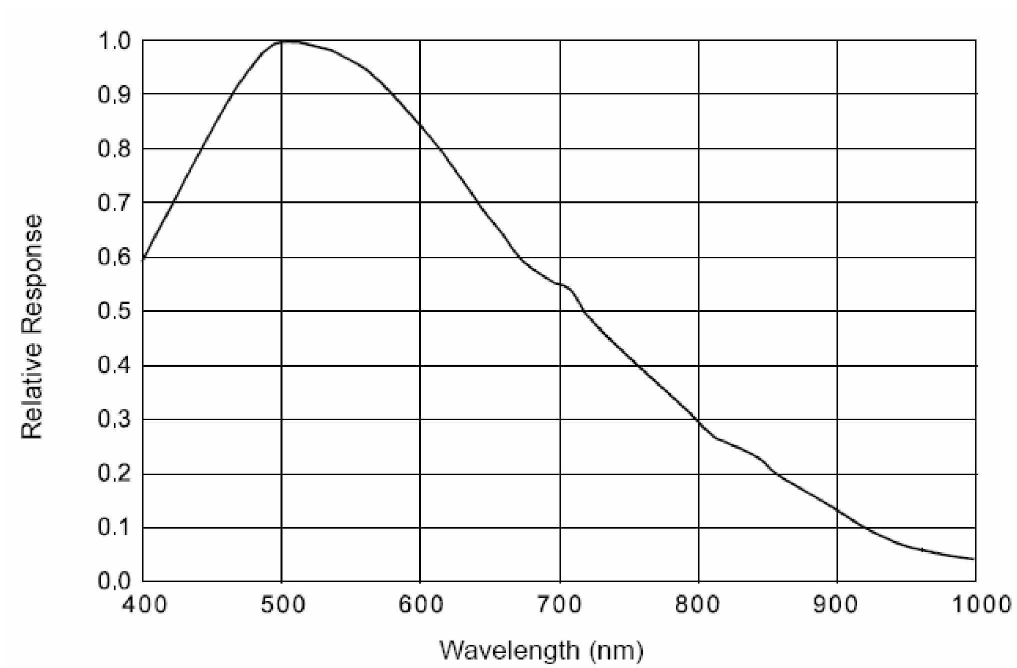


Figure 5.3 VQ-310G-M120 Spectral Response

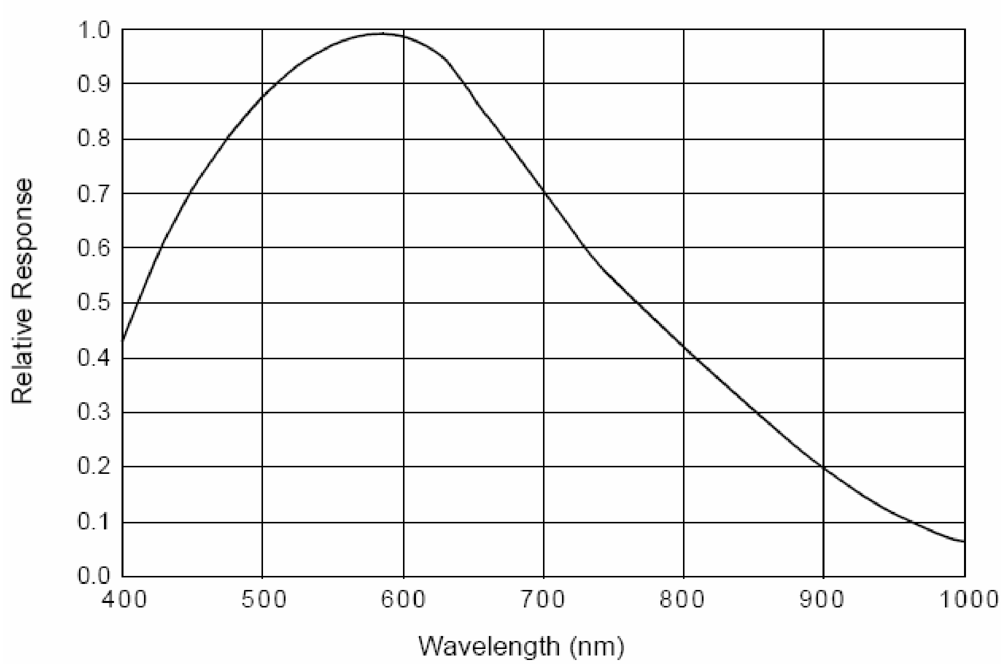


Figure 5.4 VQ-1300G-M30 Spectral Response

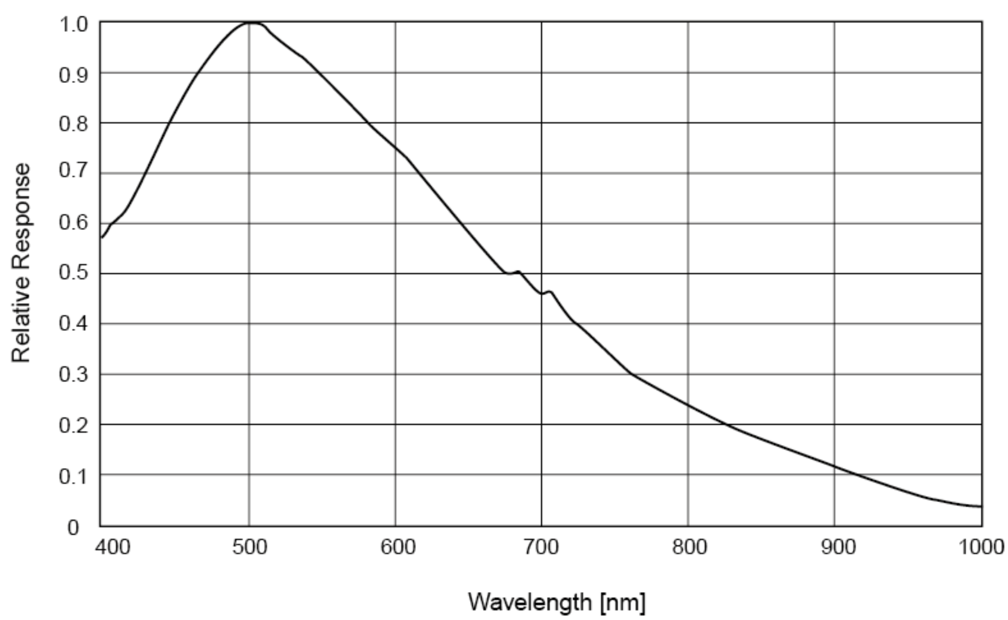


Figure 5.5 VQ-2MG-M20 Spectral Response

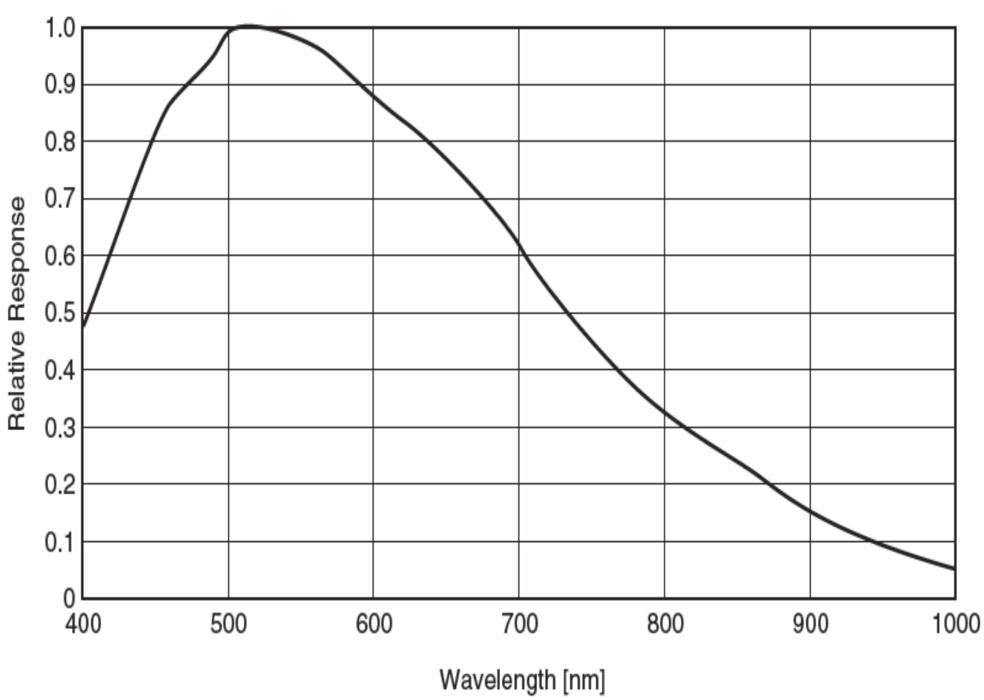


Figure 5.6 VQ-5MG-M16 Spectral Response

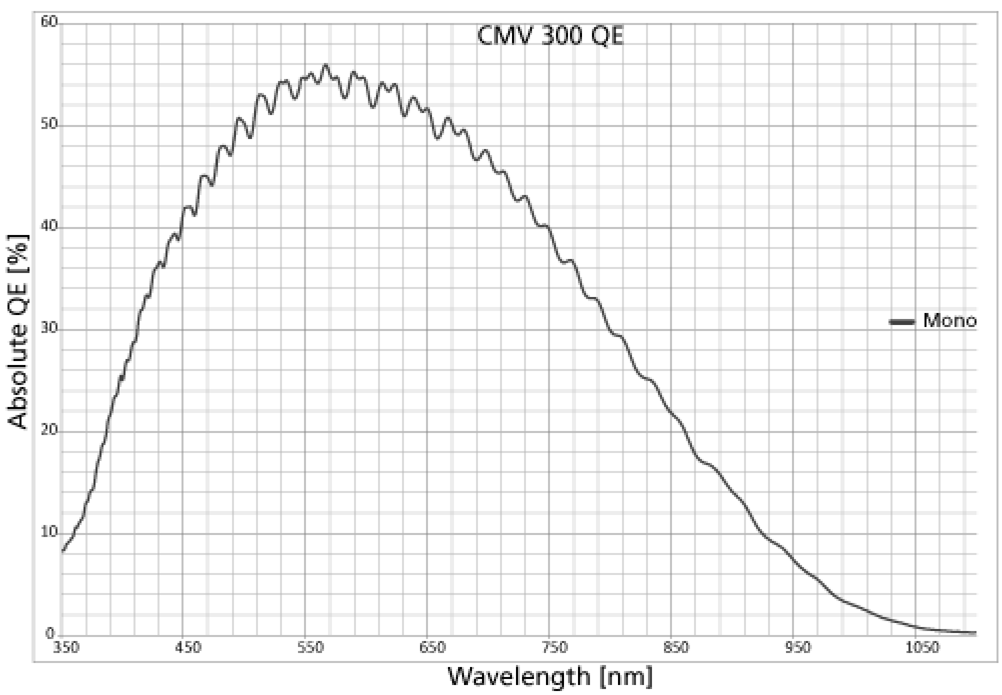


Figure 5.7 VQ-310G-M400 Spectral Response

5.5.2 Color Camera Spectral Response

The following graphs show the spectral response for VQ series color cameras.

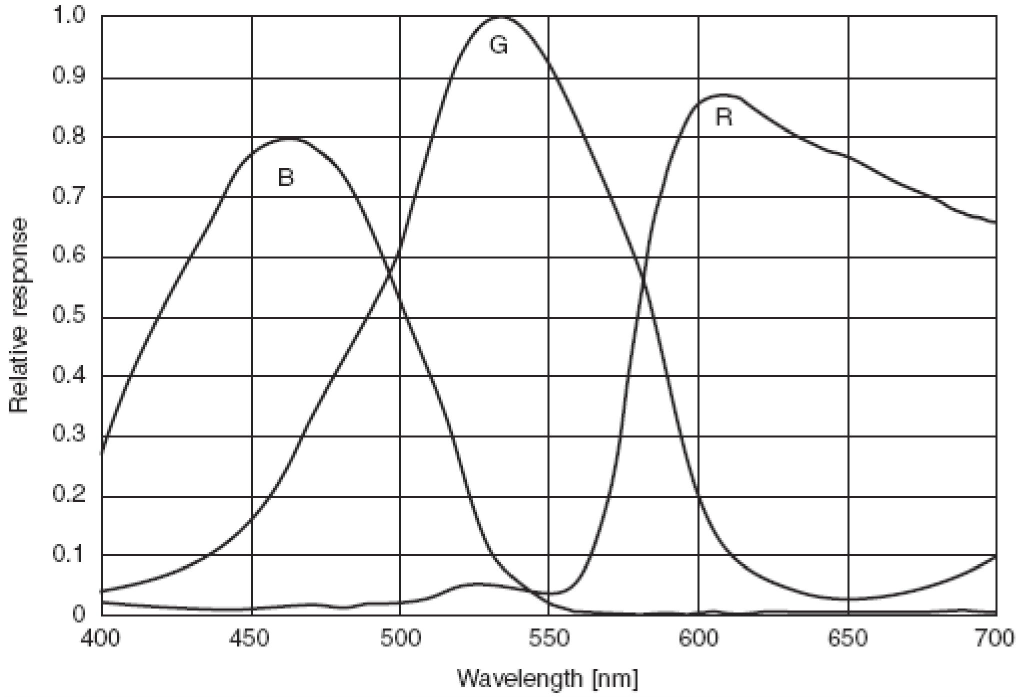


Figure 5.8 VQ-310G-C120 Spectral Response

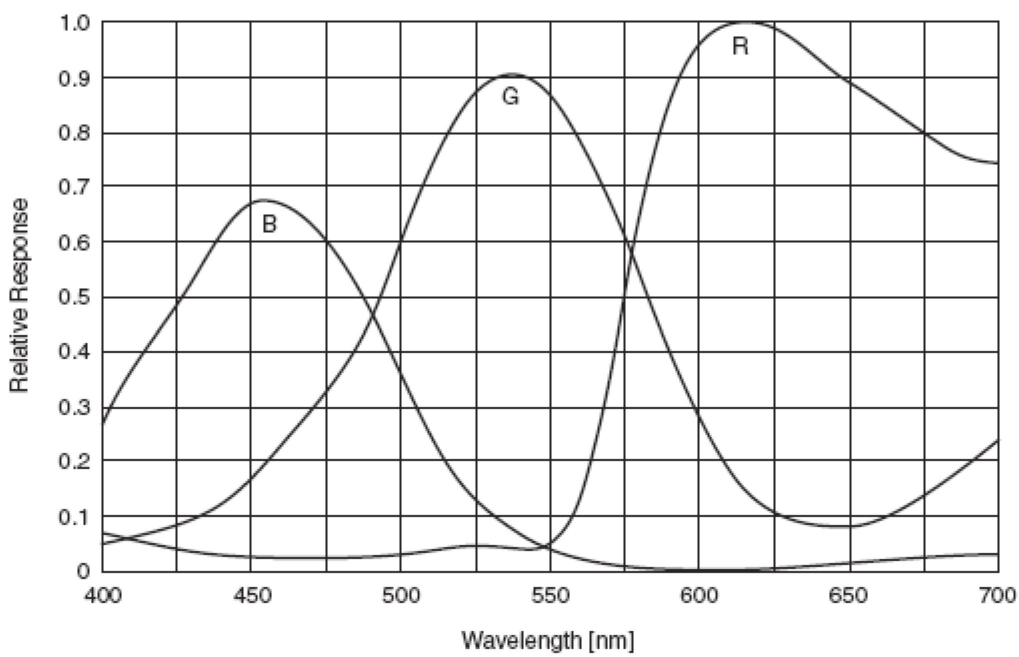


Figure 5.9 VQ-1300G-C30 Spectral Response

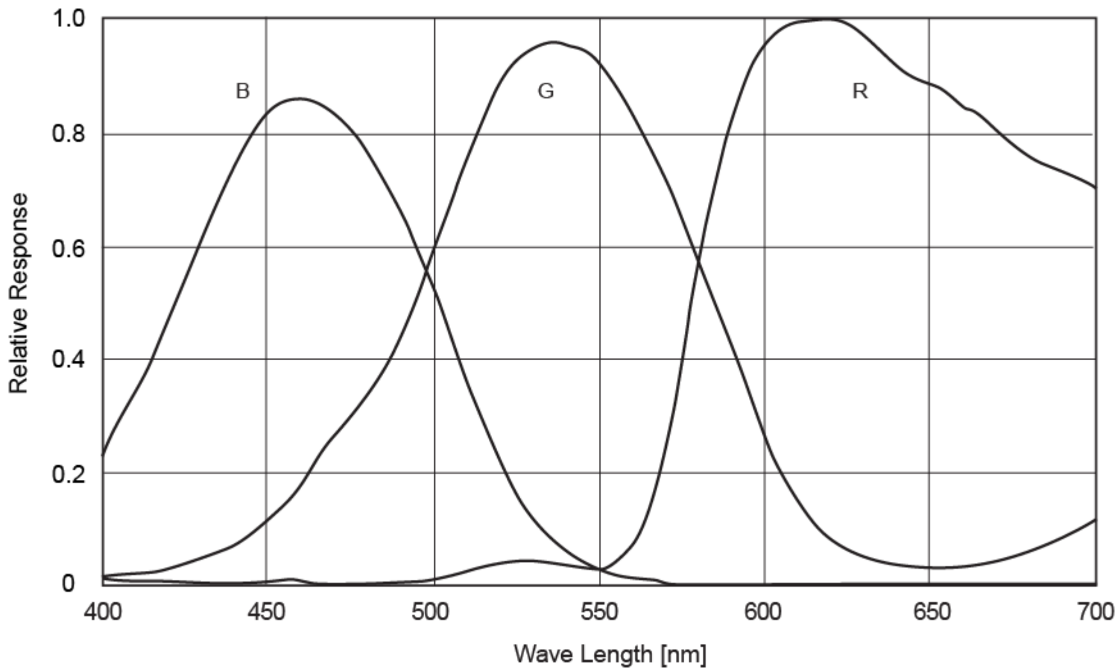


Figure 5.10 VQ-2MG-C20 Spectral Response

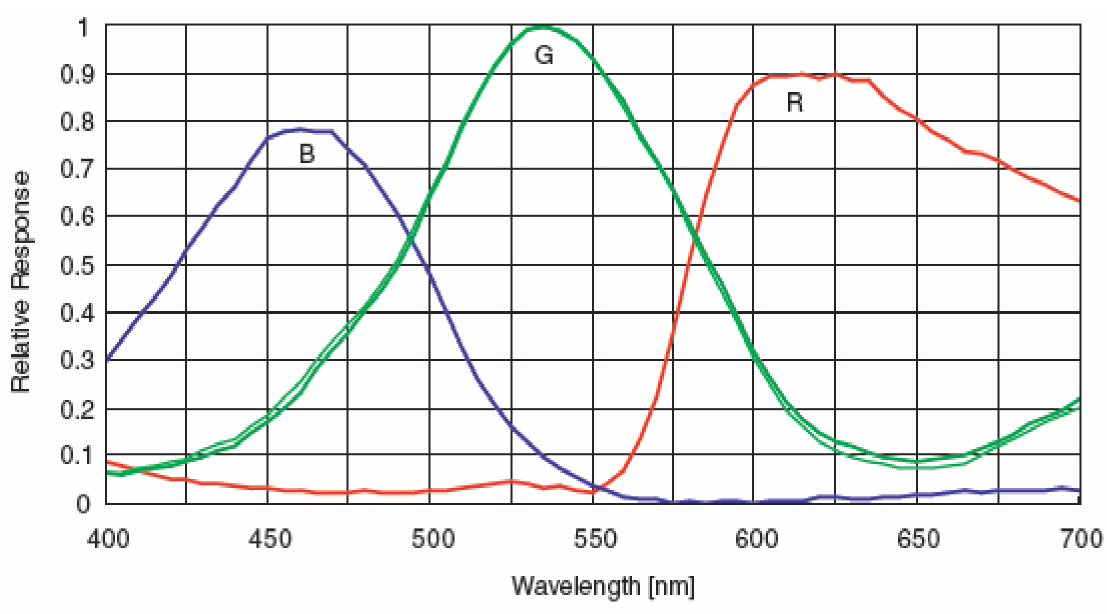


Figure 5.11 VQ-5MG-C16 Spectral Response

5.6 Mechanical Specification

The camera dimensions in millimeters are as shown in the following figure.

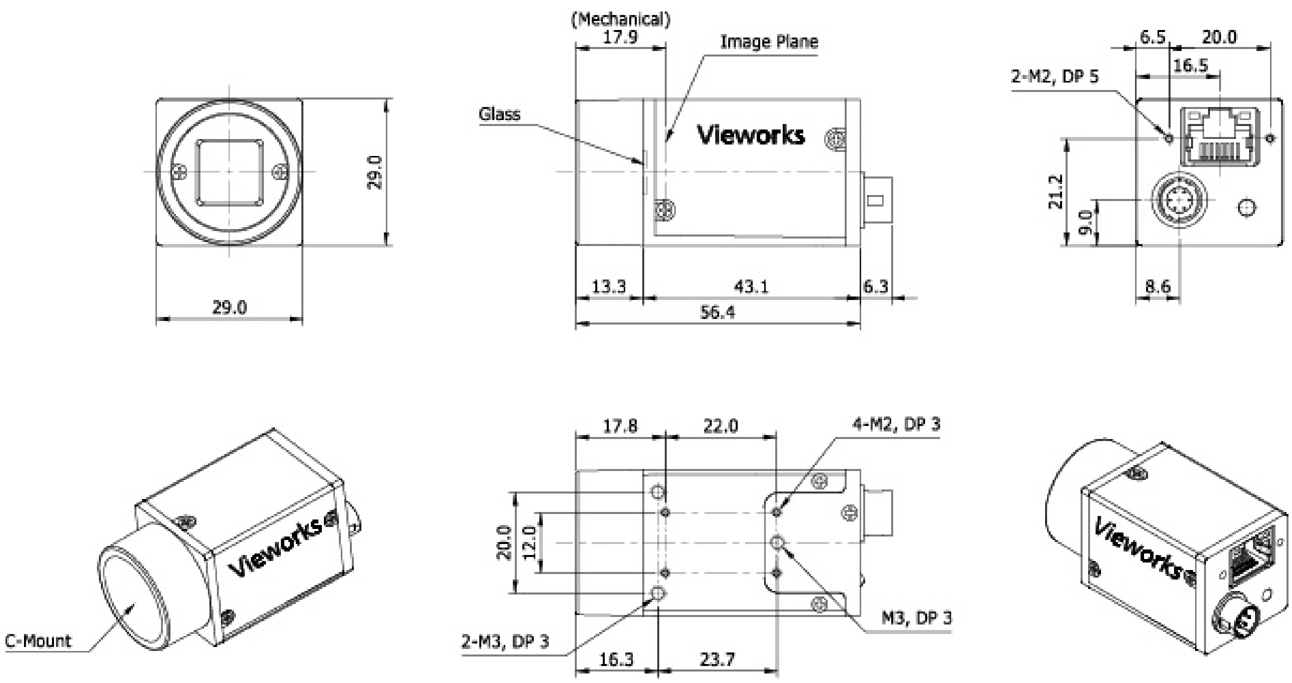


Figure 5.12 VQ-310G-120, 1300G-30 and 2MG-20 C-mount Mechanical Dimension

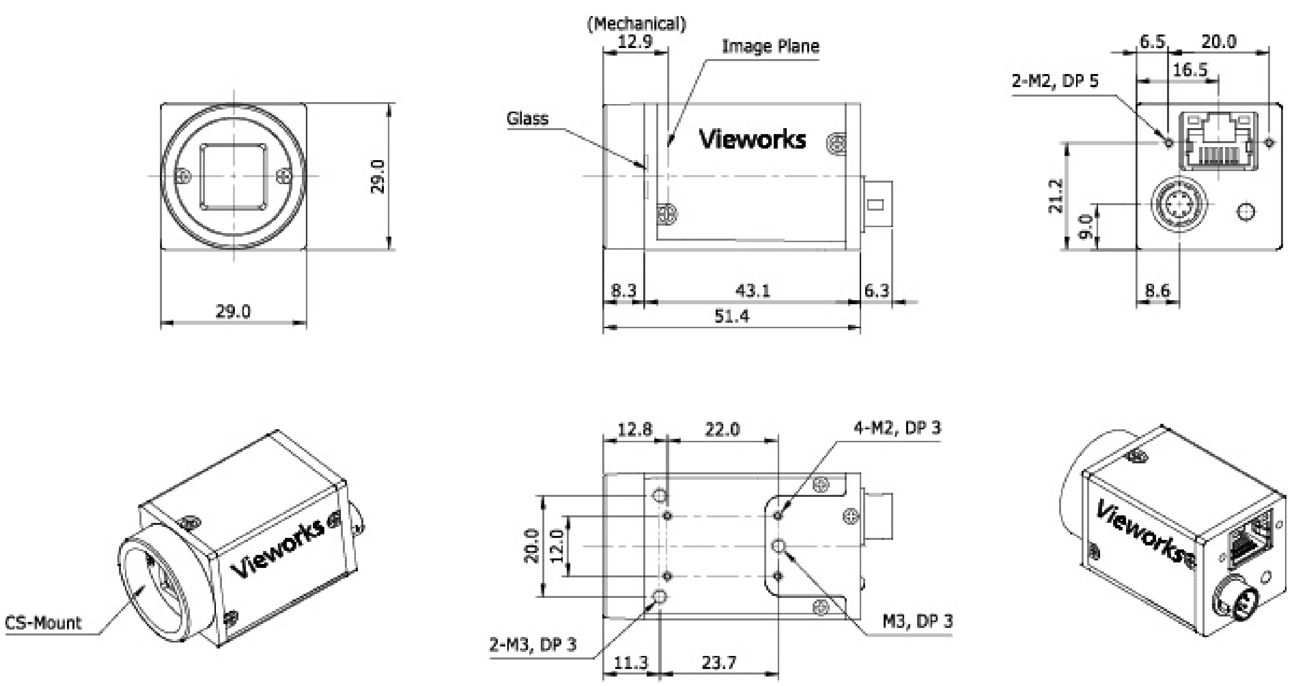


Figure 5.13 VQ-310G-120, 1300G-30 and 2MG-20 CS-mount Mechanical Dimension

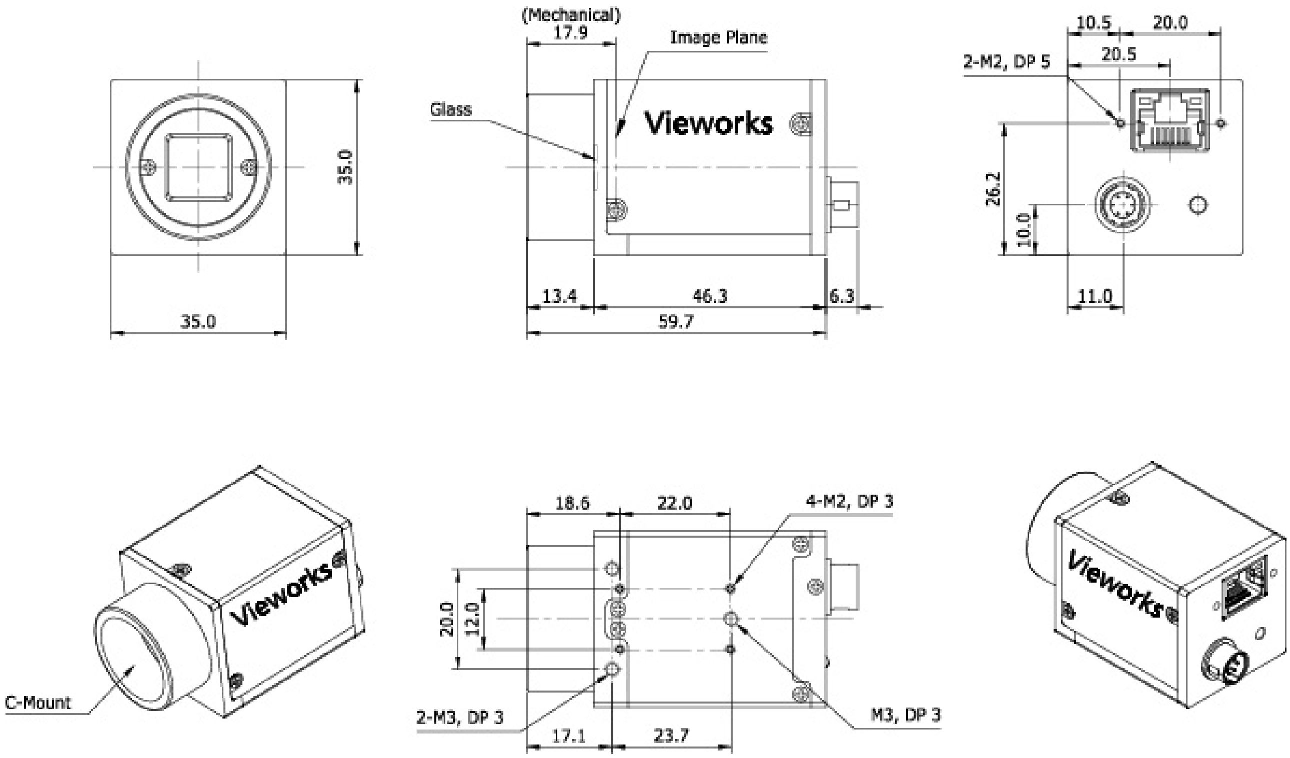


Figure 5.14 VQ-5MG-16 C-mount Mechanical Dimension

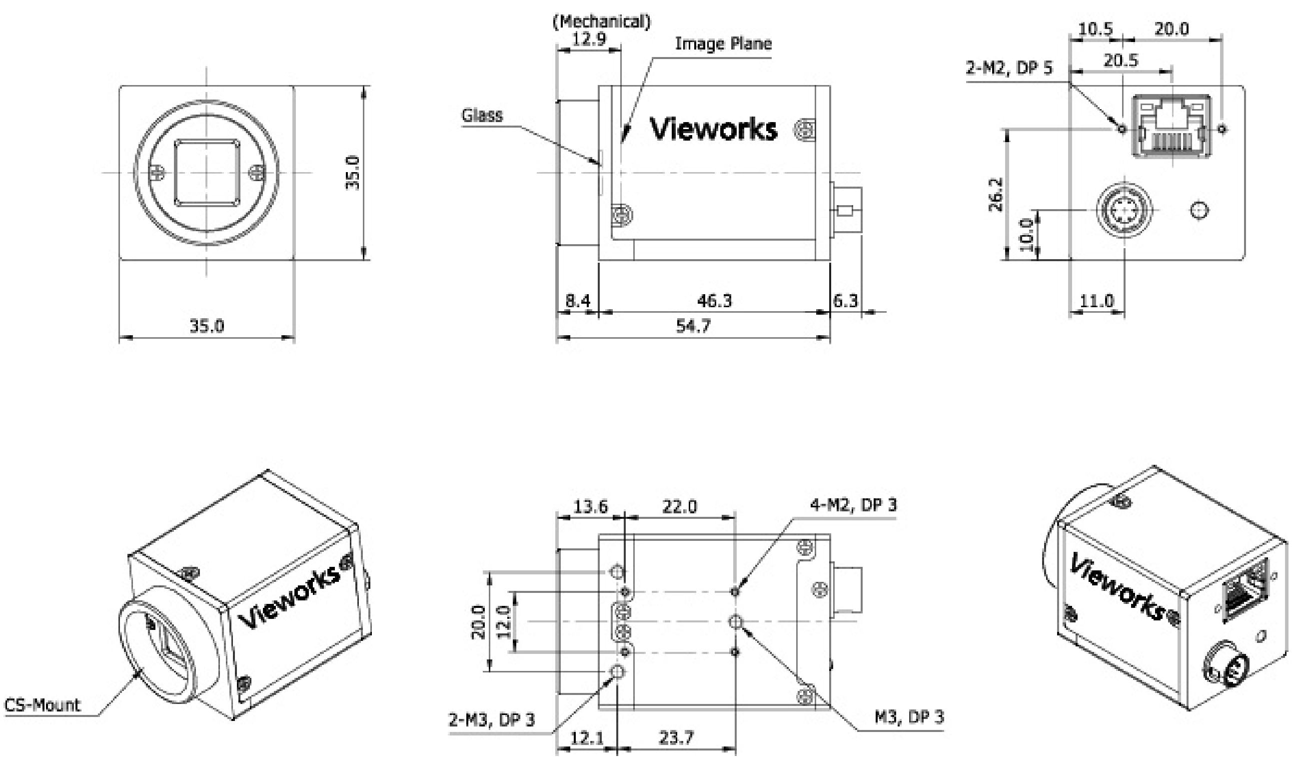


Figure 5.15 VQ-5MG-16 CS-mount Mechanical Dimension

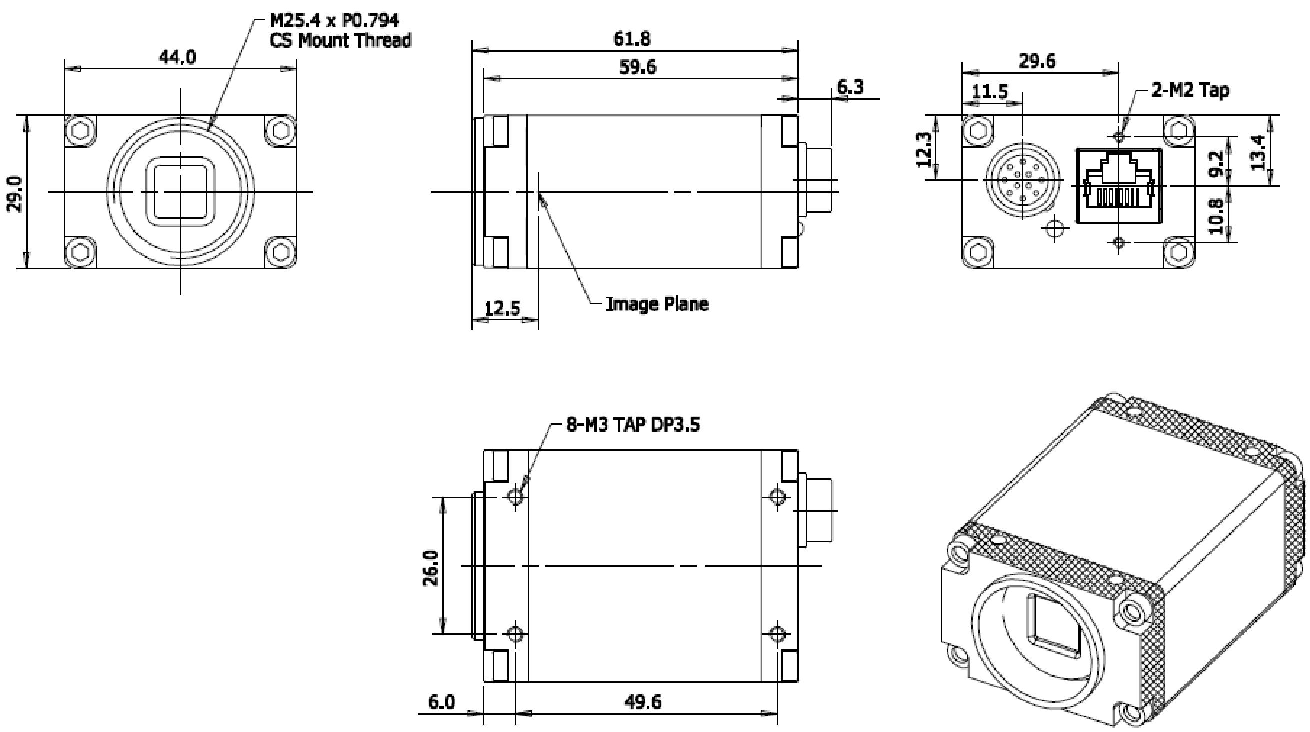


Figure 5.16 VQ-310G-M400 CS-mount Mechanical Dimension

6 Software Licensing Information

The software in VQ series includes the lightweight IP (lwIP) TCP/IP implementation. The software licensing information for this implementation is as follows.

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7 Installation

The following instructions assume that you have installed an Ethernet card including related software and Vieworks Imaging Solution. For more information, refer to Vieworks Imaging Solution Installation Manual.
To connect the camera to your PC, follow the steps below.

1. Make sure that the power supply is not connected to the camera and your PC is turned off.

- Go on to step 2 if you are using a power supply.
- Go on to step 3 if you are using a Power over Ethernet (PoE) injector.

2. **If you are using a power supply:**
   a. Plug one end of an Ethernet cable into the RJ45 jack on the camera and the other end of the Ethernet cable into the Ethernet card in your PC.
   b. Connect the plug of the power adapter to the 6-pin Power Input and Control I/O receptacle on the camera.
   c. Plug the power adapter into a working electrical outlet.

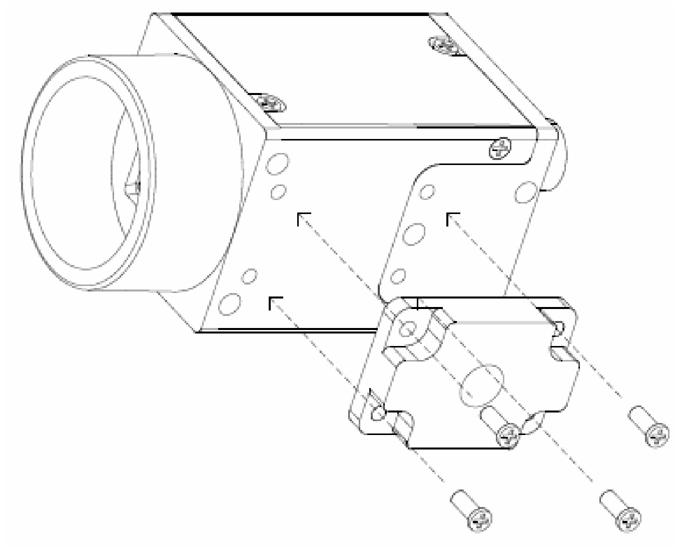
3. **If you are using a PoE injector:**
   a. Plug one end of an Ethernet cable into the network connector on the PoE injector and the other end of the Ethernet cable into the Ethernet card in your PC.
   b. Plug the PoE injector into a working electrical outlet.
   c. Connect one end of an Ethernet cable to the network connector on the PoE injector labeled “PoE” and plug the other end of the cable into the RJ45 jack on the camera.

4. Verify all the cable connections are secure.

Precaution for using Power over Ethernet

CAUTION	• Make sure that your Ethernet card or Power over Ethernet injector is compliant with IEEE 802.af standard if you want to supply power to the camera using PoE. • Yon do not need to connect a power adapter to the camera if you supply power to the camera using PoE. • The PoE feature is not supported on VQ-310G-M400.

7.1 Mount Plate (Except VQ-310G-M400)



- The mount plate is provided as an optional item.
- The camera can be fixed without using this mount plate.

7.2 Precaution to Center the Image Sensor

- Users do not need to center the image sensor as it is adjusted as factory default settings.
- When you need to adjust the center of the image sensor, please contact your local dealer or the manufacturer for technical assistance.

7.3 Precaution about Blurring Compared to Center

- Users do not need to adjust the tilt as it is adjusted as factory default settings.
- If the tilt settings need to be adjusted inevitably, please contact your local dealer or factory representative for technical support.

7.4 Installing Vieworks Imaging Solution

You can download the Vieworks Imaging Solution at machinevision.vieworks.com. You should perform the software installation first and then the hardware installation.

8 Camera Interface

8.1 General Description

As shown in the figure below, 2 types of connectors and a status indicator LED are located on the back of the camera and have the functions as follows

- ① RJ-45 Jack: controls video data and the camera. Since the camera is Power over Ethernet capable, the jack can also be used to provide power to the camera.
- ② 6 pin Circular Receptacle (male): provides access to the camera's I/O lines and power to the camera (if PoE is not used).
- ③ Status LED (Green): displays power status and operation mode.
- ④ 12 pin Circular Receptacle (male): provides access to the camera's I/O lines and power to the camera.

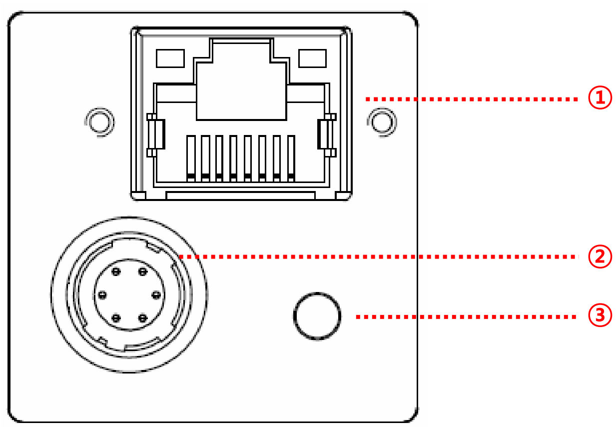


Figure 8.1 VQ Series Back Panel

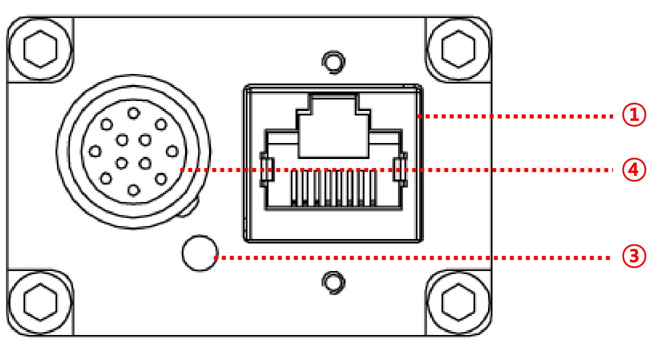


Figure 8.2 VQ-310G-M400 Back Panel

8.2 RJ-45 Jack

The 8-pin RJ-45 jack provides Ethernet access to the camera. The jack can also be used to provide Power over Ethernet (IEEE 802.af compliant) to the camera. Pin assignments for the RJ-45 jack adhere to the Ethernet standard.

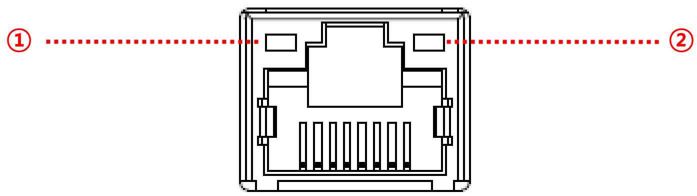


Figure 8.3 RJ-45 Jack

- ① Ethernet Link LED (Green): LED is lit when Ethernet link is active.
- ② Ethernet Active LED (Orange): LED blinks when Rx/Tx is active.

PAIR List	Pin	Signal Name	Type	Description
PAIR 0	1	+TXA	Differential	Gigabit Ethernet Transceiver
	2	-TXA	Differential	Gigabit Ethernet Transceiver
PAIR 1	3	+TXB	Differential	Gigabit Ethernet Transceiver
	6	-TXB	Differential	Gigabit Ethernet Transceiver
PAIR 2	4	+TXC	Differential	Gigabit Ethernet Transceiver
	5	-TXC	Differential	Gigabit Ethernet Transceiver
PAIR 3	7	+TXD	Differential	Gigabit Ethernet Transceiver
	8	-TXD	Differential	Gigabit Ethernet Transceiver

Table 8.1 Pin Assignments for the RJ-45 Jack

8.3 Power Input and Control I/O Receptacle (Except VQ-310G-M400)

The Power Input and Control I/O receptacle is a Hirose 6-pin connector (part # HR10A-7R-6PB) and consists of a power input, an external trigger signal input and I/O (default: Strobe) output port.

The pin assignments and configurations are as follows:

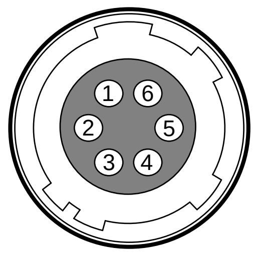


Figure 8.4 Pin Assignments for 6-pin Power Input and Control I/O Receptacle

Pin Number	Signal	Type	Description
1	+12V DC	Input	Camera Power +12V DC
2	Trigger Input +	Input	-
3	Trigger Input -	Input	-
4	I/O Output + (Default: Strobe Out)	Output	-
5	I/O Output -	-	-
6	DC Ground	Input	Camera Power GND

Table 8.2 Pin Arrangement of Power Input and Control I/O Receptacle

The mating connector is a Hirose 6-pin plug (part # HR10A-7P-6S) or the equivalent connectors. The power adapter is recommended to have at least 1 A current output at 12 V DC ±10% voltage output (Users need to purchase the power adapter separately).

Precaution for Power Input

- Make sure the power is turned off before connecting the power cord to the camera. Otherwise, damage to the camera may result.
- If the camera input voltage is greater than 38 V, damage to the camera may result.

8.4 Power Input and Control I/O Receptacle (VQ-310G-M400)

VQ-310G-M400's Power Input and Control I/O receptacle is a Hirose 12-pin connector (part # HR10A-10R-12PB). The pin assignments and configurations are as follows:

Figure 8.5 Pin Assignments for 12-pin Power Input and Control I/O Receptacle (VQ-310G-M400)

Pin Number	Signal	Type	Description
1	DC Ground	Input	Camera Power GND
2	+12 V DC	Input	Camera Power +12V DC
3	I/O Output -	Output	-
4	I/O Output + (Default: Strobe Out)	Output	-
5	Trigger Input -	Input	-
6	Trigger Input +	Input	-
7-12	N/C	–	–

Table 8.3 Pin Arrangement of Power Input and Control I/O Receptacle (VQ-310G-M400)

The mating connector is a Hirose 12-pin plug (part # HR10A-10P-12S) or the equivalent connectors. The power adapter is recommended to have at least 1 A current output at 12 V DC ±10% voltage output (Users need to purchase the power adapter separately).

Precaution for Power Input

CAUTION	• Make sure the power is turned off before connecting the power cord to the camera. Otherwise, damage to the camera may result. • If the camera input voltage is greater than 14 V, damage to the camera may result.

8.5 Trigger Input Circuit

The following figure shows trigger signal input circuit of the 6-pin and 12-pin connectors. Transmitted trigger signal is applied to the internal circuit through a photo coupler. Minimum trigger width that can be recognized by the camera is 1 ㎲. If transmitted trigger signal is less than 1 ㎲, the camera will ignore the trigger signal. External trigger circuit example is shown below.

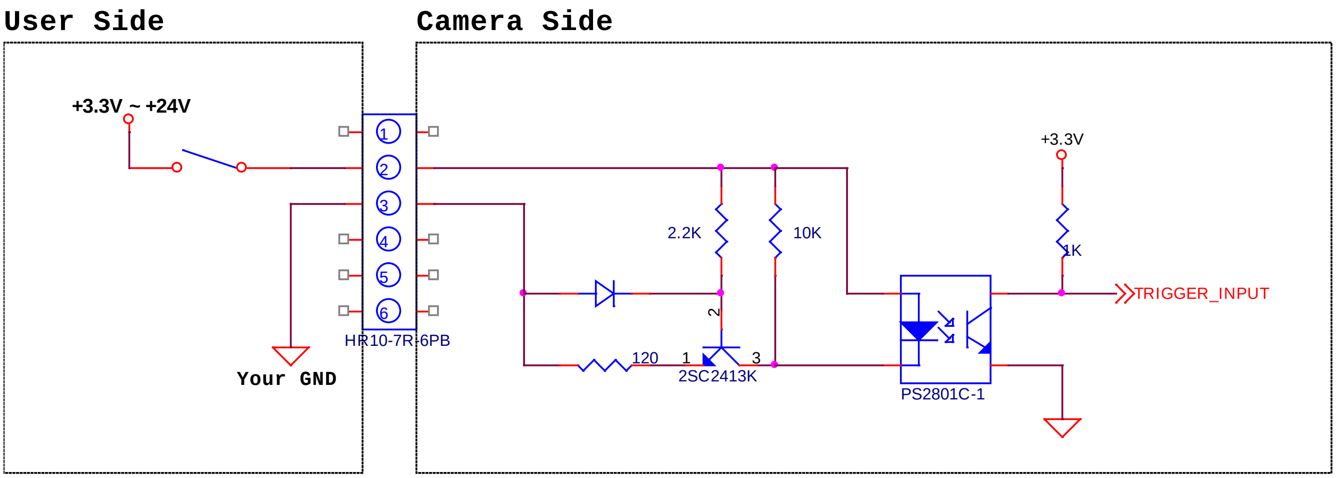


Figure 8.6 Trigger Input Schematic

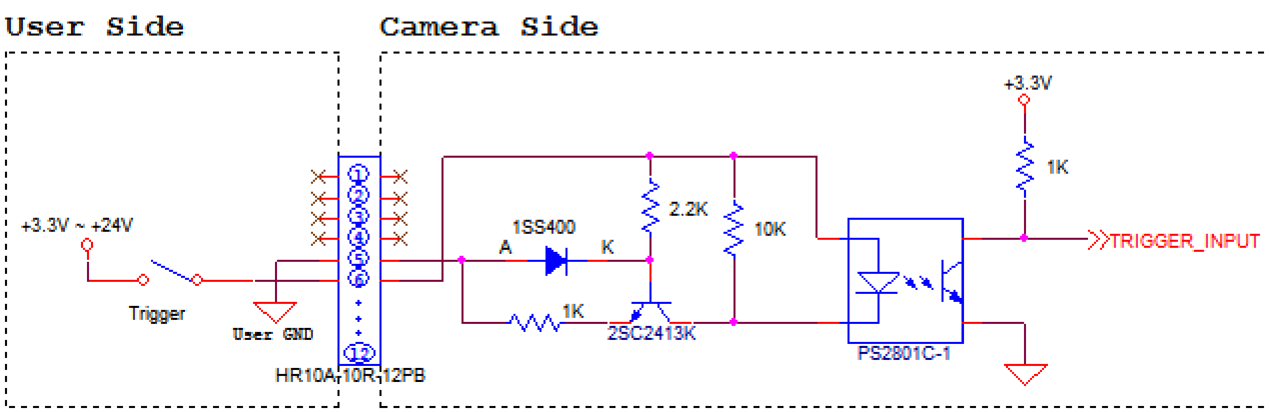


Figure 8.7 Trigger Input Schematic (VQ-310G-M400)

8.6 I/O Output Circuit

The following figure shows I/O output circuit of the 6-pin and 12-pin connectors. You can change the I/O output by setting the Digital IO control (refer to chapter 10.16 Digital IO Control).

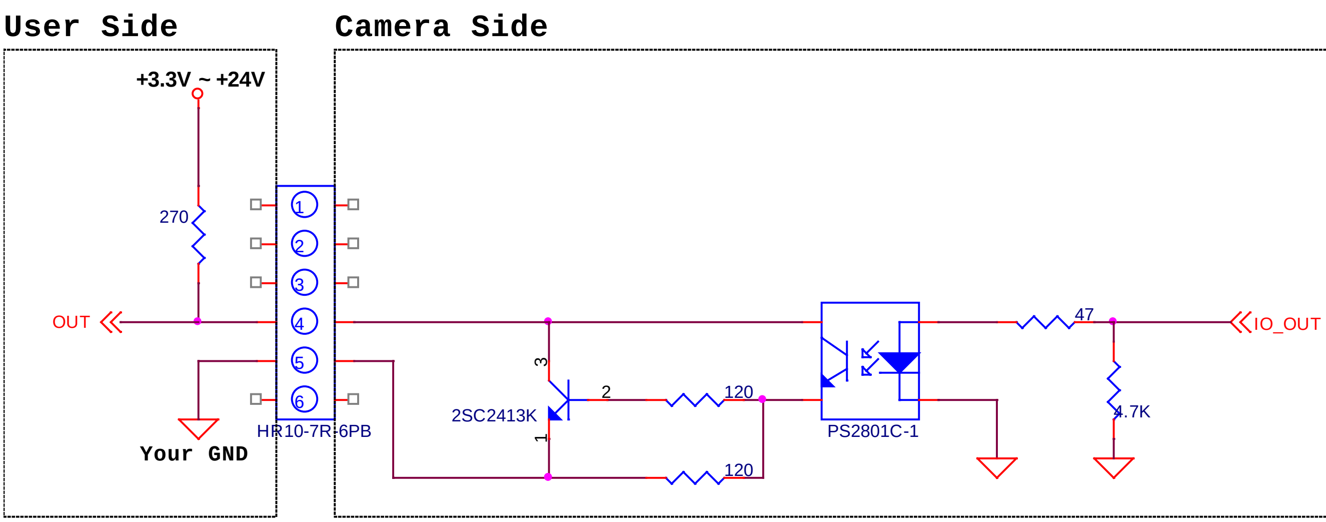


Figure 8.8 I/O Output Schematic

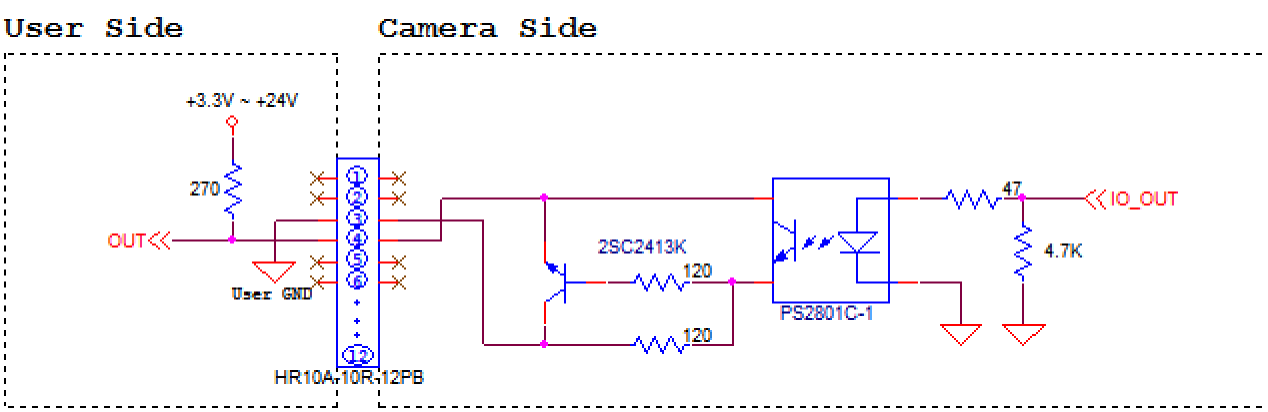


Figure 8.9 I/O Output Schematic (VQ-310G-M400)

9 Acquisition Control

This chapter provides detailed information about controlling image acquisition.

- Triggering image acquisition
- Setting the exposure time
- Controlling the camera's image acquisition rate
- Variation of the camera's maximum allowed image acquisition rate according to the camera settings

9.1 Overview

This section presents an overview of the elements involved with controlling the acquisition of images.

Three major elements are involved in controlling the acquisition of images:

- **Acquisition Start** and **Acquisition Stop** commands and the **Acquisition Mode** parameter
- The exposure start trigger
- Exposure time control

When reading the explanations in the overview and in this entire chapter, keep in mind that the term **frame** is typically used to mean a single acquired image.

Acquisition Start and Stop Commands and the Acquisition Mode

The **Acquisition Start** command prepares the camera to acquire frames. The camera cannot acquire frames unless an **Acquisition Start** command has first been executed.

A parameter called the **Acquisition Mode** has a direct bearing on how the **Acquisition Start** command operates.

If the **Acquisition Mode** parameter is set to **Single Frame**, you can only acquire one frame after executing an **Acquisition Start** command. When one frame has been acquired, the **Acquisition Start** command will expire. Before attempting to acquire another frame, you must execute a new **Acquisition Start** command.

If the **Acquisition Mode** parameter is set to **Continuous**, an **Acquisition Start** command does not expire after a single frame is captured. Once an **Acquisition Start** command has been executed, you can acquire as many frames as you like. The **Acquisition Start** command will remain in effect until you execute an **Acquisition Stop** command. Once an **Acquisition Stop** command has been executed, the camera will not be able to acquire frames until a new **Acquisition Start** command is executed.

Exposure Start Trigger

Applying an exposure start trigger signal to the camera will exit the camera from the *waiting for exposure start trigger* acquisition status and will begin the process of exposing and reading out a frame (see Figure 9.1).

As soon as the camera is ready to accept another exposure start trigger signal, it will return to the *waiting for exposure start trigger* acquisition status. A new exposure start trigger signal can then be applied to the camera to begin another frame exposure.

The exposure start trigger has two modes: off and on.

If the **Trigger Mode** parameter is set to **Off**, the camera will generate all required exposure start trigger signals internally, and you do not need to apply exposure start trigger signals to the camera. The rate at which the camera will generate the signals and acquire frames will be determined by the way that you set several frame rate related parameters.

If the **Trigger Mode** parameter is set to **On**, you must trigger exposure start by applying exposure start trigger signals to the camera. Each time a trigger signal is applied, the camera will begin a frame exposure. When exposure start is being triggered in this manner, it is important that you do not attempt to trigger frames at a rate that is greater than the maximum allowed (There is a detailed explanation about the maximum allowed frame rate at the end of this chapter.). Exposure start trigger signals applied to the camera when it is not in a *waiting for exposure start trigger* acquisition status will be ignored.

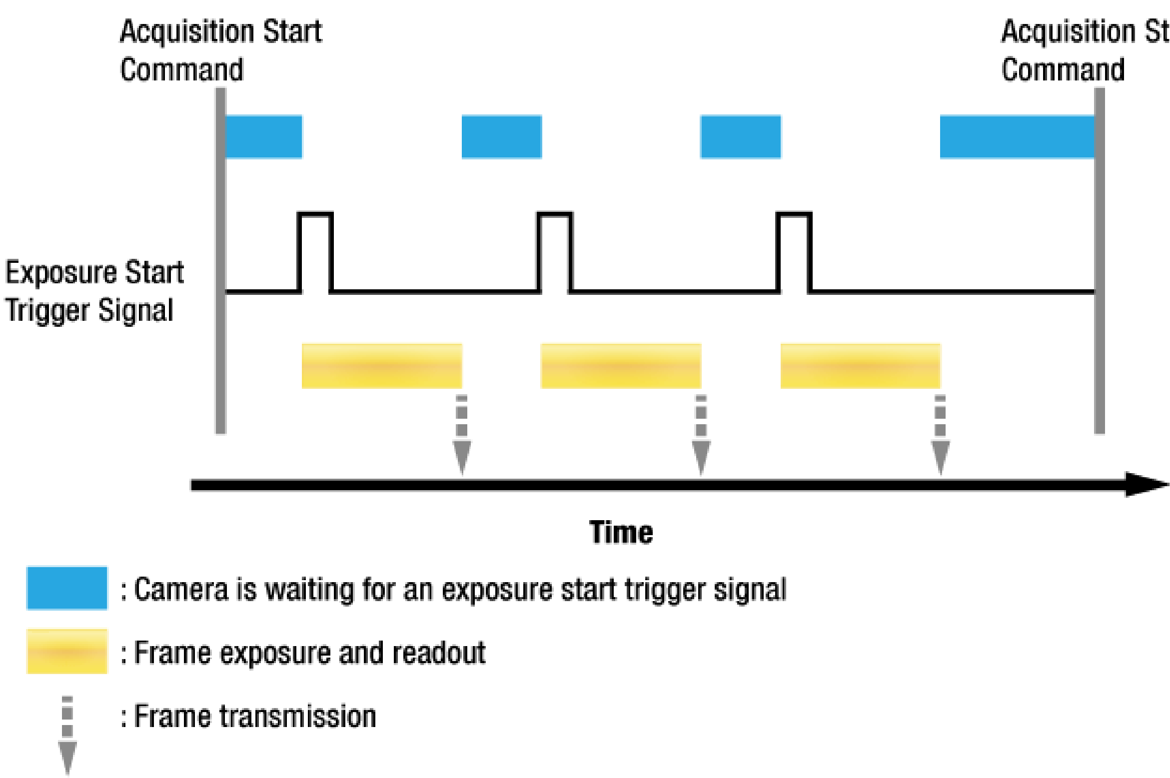


Figure 9.1 Exposure Start Triggering

Applying Trigger Signals

The paragraphs above mention "applying a trigger signal". There are two ways to apply an exposure start trigger signal to the camera: via software or via external (commonly referred to as hardware).

To apply trigger signals via **Software**, you must set the **Trigger Source** parameter to **Software**. At that point, each time a **Trigger Software** command is executed, the exposure start trigger signal will be applied to the camera.

To apply trigger signals via **External**, you must set the **Trigger Source** parameter to **External**. At that point, each time a proper electrical signal is applied to the camera, an occurrence of the exposure start trigger signal will be recognized by the camera.

Exposure Time Control

When an exposure start trigger signal is applied to the camera, the camera will begin to acquire a frame.

A critical aspect of frame acquisition is how long the pixels in the camera's sensor will be exposed to light during the frame acquisition.

If the **Trigger Source** parameter is set to **Software**, a parameter called the **Exposure Time** will determine the exposure time for each frame. At this point, you must set the **Exposure Mode** parameter to **Timed**.

If the **Trigger Source** parameter is set to **External**, there are two modes of operation: **Timed** and **Trigger Width**.

With the **Timed** mode, the **Exposure Time** parameter will determine the exposure time for each frame.

With the **Trigger Width** mode, the way that you manipulate the rise and fall of the external signal will determine the exposure time. The **Trigger Width** mode is especially useful if you want to change the exposure time from frame to frame.

9.2 Acquisition Start/Stop Commands and Acquisition Mode

Executing an **Acquisition Start** command prepares the camera to acquire frames. You must execute an **Acquisition Start** command before you can begin acquiring frames. Executing an **Acquisition Stop** command terminates the camera's ability to acquire frames. When the camera receives an **Acquisition Stop** command:

- If the camera is not in the process of acquiring a frame, its ability to acquire frames will be terminated immediately.
- If the camera is in the process of acquiring a frame, the frame acquisition process will be allowed to finish and the camera's ability to acquire new frames will be terminated.

The camera's **Acquisition Mode** parameter has three settings: **Single Frame**, **Multi-Frame** and **Continuous**. The use of **Acquisition Start** and **Acquisition Stop** commands and the camera's **Acquisition Mode** parameter setting are related.

If the camera's **Acquisition Mode** parameter is set to **Single Frame**, after an **Acquisition Start** command has been executed, a single frame can be acquired. When acquisition of one frame is complete, the camera will execute an **Acquisition Stop** command internally and will no longer be able to acquire frames. To acquire another frame, you must execute a new **Acquisition Start** command.

If the camera's **Acquisition Mode** parameter is set to **Multi-Frame**, after an **Acquisition Start** command has been executed, exposure start can be triggered as many as specified by the **Acquisition Frame Count** parameter. The camera will continue to react to exposure start trigger signals until the number of exposure start trigger signals it has received is equal to the current **Acquisition Frame Count** parameter setting.

CAUTION	With **Single Frame** or **Multi-Frame Acquisition Mode**, if you execute another **Acquisition Start** command while the camera is in the process of acquiring a frame, an error may occur.

If the camera's **Acquisition Mode** parameter is set to **Continuous**, after an **Acquisition Start** command has been executed, exposure start can be triggered as desired. Each time an exposure start trigger is applied while the camera is in a waiting for *exposure start trigger* acquisition status, the camera will acquire and transmit a frame. The camera will retain the ability to acquire frames until an **Acquisition Stop** command is executed. Once the **Acquisition Stop** command is received, the camera will no longer be able to acquire frames.

When the camera's **Acquisition Mode** is set to **Single Frame**, the maximum possible acquisition frame rate for a given ROI cannot be achieved. This is true because the camera performs a complete internal setup cycle for each single frame and because it cannot be operated with **Trigger Overlap**. To achieve the maximum possible acquisition frame rate, set the **Acquisition Mode** to **Continuous** and **Trigger Overlap** to **Readout**.

9.3 Exposure Start Trigger

The exposure start trigger is used to begin frame acquisition. Exposure start trigger signals can be generated within the camera or may be applied externally as **Software** or **External** exposure start trigger signals. If an exposure start trigger signal is applied to the camera, the camera will begin to expose a frame.

9.3.1 Trigger Mode

The main parameter associated with the exposure start trigger is the **Trigger Mode** parameter. The **Trigger Mode** parameter for the exposure start trigger has two available settings: **Off** and **On**.

9.3.1.1 Trigger Mode = Off

When the **Trigger Mode** parameter is set to **Off**, the camera will generate all required exposure start trigger signals internally, and you do not need to apply exposure start trigger signals to the camera.
With the **Trigger Mode** set to **Off**, the way that the camera will operate the exposure start trigger depends on the setting of the camera's **Acquisition Mode** parameter:

- **Single Frame**: The camera will automatically generate a single exposure start trigger signal whenever it receives an **Acquisition Start** command.
- **Multi-Frame**: The camera will automatically begin generating exposure start trigger signals as many as specified by the **Acquisition Frame Count** parameter when it receives an **Acquisition Start** command. The camera will continue to generate exposure start trigger signals until the number of exposure start trigger signals it has received is equal to the current **Acquisition Frame Count** parameter setting or until it receives an **Acquisition Stop** command.

With **Single Frame** or **Multi-Frame Acquisition Mode**, if you execute another **Acquisition Start** command while the camera is in the process of acquiring a frame, an error may occur.

When the **Acquisition Mode** parameter is set to **Multi-Frame**, you must set the value of the camera's **Acquisition Frame Count** parameter. The value of the **Acquisition Frame Count** can range from 1 to 255.

- **Continuous**: The camera will automatically begin generating exposure start trigger signals when it receives an **Acquisition Start** command. The camera will continue to generate exposure start trigger signals until it receives an **Acquisition Stop** command.

Free Run

- When you set the **Trigger Mode** parameter to **Off** and the **Acquisition Mode** parameter to **Continuous**, the camera will generate all required trigger signals internally. When the camera is set this way, it will constantly acquire images without any need for triggering by the user. This use case is commonly referred as “free run”.
- When you operate the camera in free run, you must set the **Trigger Overlap** parameter to **Readout** to achieve optimal camera performance.

The rate at which the exposure start trigger signals are generated may be determined by the camera’s **Acquisition Frame Rate** parameter:

- If the parameter is set to a value less than the maximum allowed frame rate with the current camera settings, the camera will generate exposure start trigger signals at the rate specified by the parameter setting.
- If the parameter is set to a value greater than the maximum allowed frame rate with the current camera settings, the camera will generate exposure start trigger signals at the maximum allowed frame rate.

Exposure Time Control with Trigger Mode = Off

When the **Trigger Mode** parameter is set to **Off**, the exposure time for each frame acquisition is determined by the value of the camera’s **Exposure Time** parameter. For more information about the **Exposure Time** parameter, see 9.4 Setting the Exposure Time.

9.3.1.2 Trigger Mode = On

When the **Trigger Mode** parameter is set to **On**, you must apply an exposure start trigger signal to the camera each time you want to begin a frame acquisition. The **Trigger Source** parameter specifies the source signal that will act as the exposure start trigger signal.

The available settings for the **Trigger Source** parameter are:

- **Software**: You can apply an exposure start trigger signal to the camera by executing a **Trigger Software** command for the exposure start trigger on your computer.
- **External**: You can apply an exposure start trigger signal to the camera by injecting an externally generated electrical signal (commonly referred to as a hardware trigger signal) into the Power Input and Control I/O Receptacle pin 2 (pin 6 for VQ-310G-M400) on the camera.

If the **Trigger Source** parameter is set to **External**, you must also set the **Trigger Activation** parameter.

The available settings for the **Trigger Activation** parameter are:

- **Rising Edge**: Specifies that a rising edge of the electrical signal will act as the exposure start trigger.
- **Falling Edge**: Specifies that a falling edge of the electrical signal will act as the exposure start trigger.

Exposure Time Control with Trigger Mode = On

When the **Trigger Mode** parameter is set to **On** and the **Trigger Source** parameter is set to **Software**, the exposure time for each frame acquisition is determined by the value of the camera's **Exposure Time** parameter.

When the **Trigger Mode** parameter is set to **On** and the **Trigger Source** parameter is set to **External**, the exposure time for each frame acquisition can be controlled with the **Exposure Time** parameter or it can be controlled by manipulating the external trigger signal.

9.3.2 Using a Software Trigger Signal

If the **Trigger Mode** parameter is set to **On** and the **Trigger Source** parameter is set to **Software**, you must apply a software trigger signal (exposure start) to the camera to begin each frame acquisition. Assuming that the camera is in a *waiting for exposure start trigger* acquisition status, frame exposure will start when the software trigger signal is received by the camera. Figure 9.2 illustrates frame acquisition with a software trigger signal.

When the camera receives a software trigger signal and begins exposure, it will exit the *waiting for exposure start trigger* acquisition status because at that point, it cannot react to a new exposure start trigger signal.

As soon as the camera is capable of reacting to a new exposure start trigger signal, it will automatically return to the *waiting for exposure start trigger* acquisition status.

When you are using a software trigger signal to start each frame acquisition, the camera's **Exposure Mode** parameter must be set to **Timed**. The exposure time for each acquired frame will be determined by the value of the camera's **Exposure Time** parameter.

When you use a software trigger signal to acquire frames, be aware that there is a Trigger Latency due to the characteristics of the Gigabit Ethernet. Use an external trigger signal to precisely synchronize the trigger signal with the exposure timing.

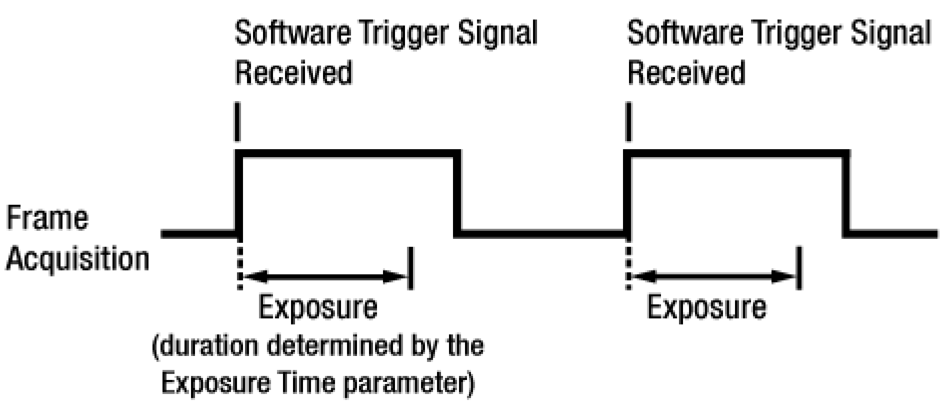


Figure 9.2 Frame Acquisition with Software Trigger Signal

When you are using a software trigger signal to start each frame acquisition, the frame rate will be determined by how often you apply a software trigger signal to the camera, and you should not attempt to trigger frame acquisition at a rate that exceeds the maximum allowed for the current camera settings. (There is a detailed explanation about the maximum allowed frame rate at the end of this chapter.)

Software trigger signals that are applied to the camera when it is not ready to receive them will be ignored.

9.3.3 Using an External Trigger Signal

If the **Trigger Mode** parameter is set to **On** and the **Trigger Source** parameter is set to **External**, an externally generated electrical signal injected into the Power Input and Control I/O Receptacle pin 2 (pin 6 for VQ-310G-M400) will act as the exposure start trigger signal for the camera. This type of trigger signal is generally referred to as a hardware trigger signal.

A rising edge or a falling edge of the external signal can be used to trigger frame acquisition. The **Trigger Activation** parameter is used to select rising edge or falling edge triggering.

Assuming that the camera is in a *waiting for exposure start trigger* acquisition status, frame acquisition will start whenever the appropriate edge transition is received by the camera.

When the camera receives an external trigger signal and begins exposure, it will exit the *waiting for exposure start trigger* acquisition status because at that point, it cannot react to a new exposure start trigger signal. As soon as the camera is capable of reacting to a new exposure start trigger signal, it will automatically return to the *waiting for exposure start trigger* acquisition status.

When the camera is operating under control of an external signal, the period of the external trigger signal will determine the rate at which the camera is acquiring frames:

$$\frac{1}{\text{External signal period in seconds}} = \text{Frame Rate}$$

For example, if you are operating a camera with an External trigger signal period of 500 ㎳ (0.5 s):

So in this case, the frame rate is 2 fps.

9.3.3.1 Exposure Modes

If you are triggering the start of frame acquisition with an externally generated trigger signal, two exposure modes are available: **Timed** and **Trigger Width**.

Timed Exposure Mode

When the **Timed** mode is selected, the exposure time for each frame acquisition is determined by the value of the camera's **Exposure Time** parameter. If the camera is set for rising edge triggering, the exposure time starts when the external trigger signal rises. If the camera is set for falling edge triggering, the exposure time starts when the external trigger signal falls. Figure 9.3 illustrates timed exposure with the camera set for rising edge triggering.

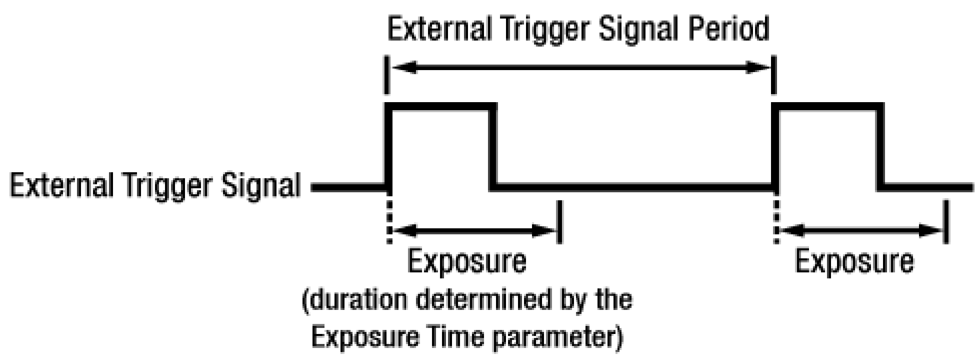


Figure 9.3 Timed Exposure Mode

Note that if you attempt to trigger a new exposure start while the previous exposure is still in progress, the trigger signal will be ignored.

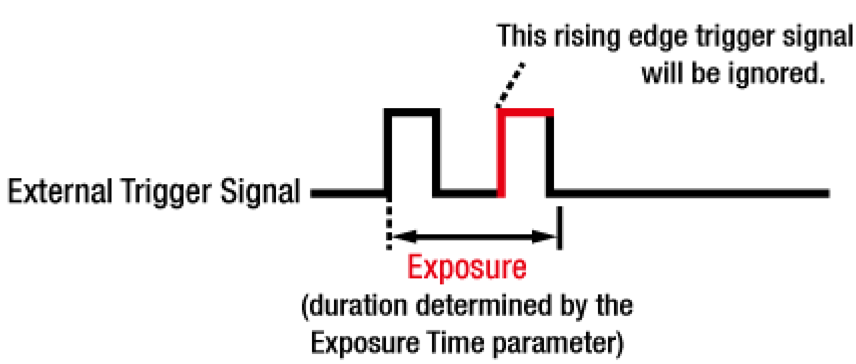


Figure 9.4 Trigger Overlapped with Timed Exposure Mode

Trigger Width Exposure Mode

When the **Trigger Width** exposure mode is selected, the length of the exposure for each frame acquisition will be directly controlled by the external trigger signal. If the camera is set for rising edge triggering, the exposure time begins when the external trigger signal rises and continues until the external trigger signal falls. If the camera is set for falling edge triggering, the exposure time begins when the external trigger signal falls and continues until the external trigger signal rises. Figure 9.5 illustrates **Trigger Width** exposure with the camera set for rising edge triggering.

Trigger Width exposure is especially useful if you intend to vary the length of the exposure time for each frame.

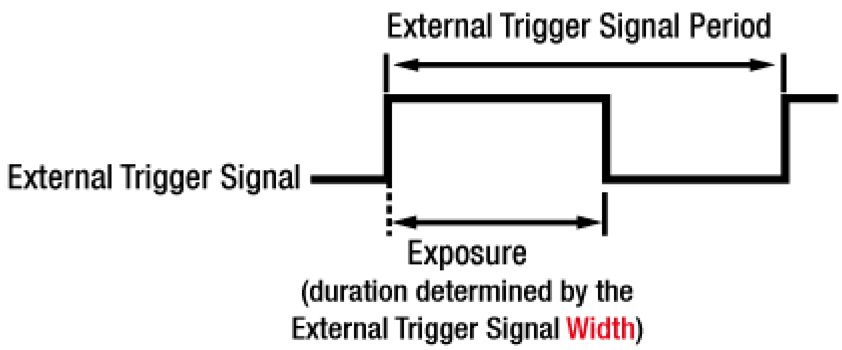


Figure 9.5 Trigger Width Exposure Mode

9.3.3.2 Double Exposure (Except VQ-310G-M400)

When the **Double Exposure** mode is selected, two frames can be acquired in rapid succession using a single trigger signal. The exposure time for the first frame begins according to the current camera settings when the trigger signal is applied to the camera. Once the exposure for the first frame is complete, the camera reads out the sensor data. At this point, the exposure time for the second frame begins. Then, the camera reads out the sensor data for the second frame after reading out the sensor data for the previous frame.

In the **Double Exposure** mode, the exposure time for the second frame equals to the readout time of the first frame. There is a just few microseconds (or dozen of microseconds) between the point where the exposure time for the first frame ends and the point where the exposure time for the second frame begins. This is because the camera cannot react to the exposure start trigger signal while reading out the sensor data for the first frame. At this point, the camera outputs a strobe out signal reflected the exposure time for the first frame.

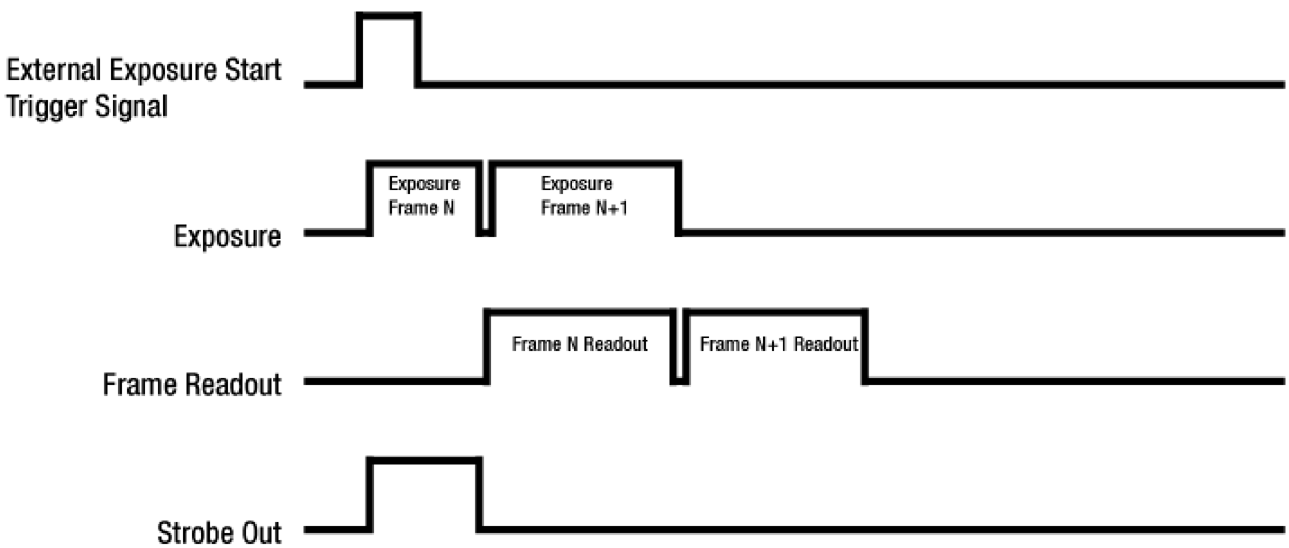


Figure 9.6 Double Exposure

9.3.4 Trigger Delay

The **Trigger Delay** feature specifies a delay (in microseconds) that will be applied between the receipt of a trigger signal (software or external) and when the trigger will become effective.

The Trigger Delay can be specified in the range from 0 to 10,000,000 μs (equivalent to 10 s).

ⓘ	The **Trigger Delay** will not operate if the **Trigger Mode** parameter is set to **Off**.

9.4 Setting the Exposure Time

This section describes how the exposure time can be adjusted manually by setting the value of the exposure time parameter.
VQ-310G, VQ-1300G and VQ-2MG-20 also have an Exposure Auto feature that can automatically adjust the exposure time.

Manual adjustment of the exposure time parameter will only work correctly if the **Exposure Auto** feature is disabled.

If you are operating the camera in any one of the following ways, you must specify an exposure time by setting the camera's **Exposure Time** parameter:

- the **Trigger Mode** is set to **Off**
- the **Trigger Mode** is set to **On** and the **Trigger Source** is set to **Software** (In this case, you must set the **Exposure Mode** parameter to **Timed**.)
- the **Trigger Mode** is set to **On**, the **Trigger Source** is set to **External**, and the **Exposure Mode** is set to **Timed**.

The **Exposure Time** parameter must not be set below a minimum specified value. The **Exposure Time** parameter sets the exposure time in ㎲. The minimum and maximum exposure time settings for each camera model are shown in the following table.

Camera Model	Minimum Allowed Exposure Time	Maximum Possible Exposure Time†
VQ-310G-120	22 ㎲	7,000,000 ㎲
VQ-1300G-30	9 ㎲	7,000,000 ㎲
VQ-2MG-20	30 ㎲	7,000,000 ㎲
VQ-5MG-16	39 ㎲	7,000,000 ㎲
VQ-310G-M400	65 ㎲	7,000,000 ㎲

†: When the **Exposure Mode** is set to **Trigger Width**, the exposure time is controlled by the external trigger signal and has no maximum limit.

Table 9.1 Minimum and Maximum Exposure Time Setting

9.4.1 Exposure Auto (Except VQ-5MG-16)

The **Exposure Auto** feature automatically adjusts the **Exposure Time** parameter within set limits until an average gray value for the pixel data from the AE Data ROI reaches an **Exposure Auto Target Level** setting value.

The **Exposure Auto** feature can be operated in the **Once** or **Continuous** modes of operation.

If the Data ROI does not overlap the Image ROI, the pixel data from the Data ROI will not be used to control the exposure time.

The **Exposure Auto** feature and the **Gain Auto** feature can be used at the same time.

When the **Trigger Width** parameter is selected for **Exposure Mode**, the **Exposure Auto** feature is not available.

For more information, refer to 10.8 Exposure Auto and Gain Auto (Except VQ-5MG-16).

9.5 Overlapping Exposure with Sensor Readout

The frame acquisition process on the camera includes two distinct parts. The first part is the exposure of the pixels in the imaging sensor. Once exposure is complete, the second part of the process – readout of the pixel values from the sensor – takes place. In regard to this frame acquisition process, there are two common ways for the camera to operate: with **Trigger Overlap** – **Off** and with **Trigger Overlap** - **Readout**.

In the **Trigger Overlap** – **Off** mode of operation, each time a frame is acquired the camera completes the entire exposure/readout process before acquisition of the next frame is started. The exposure for a new frame does not overlap the sensor readout for the previous frame. Figure 9.7 illustrates the **Trigger Overlap** parameter set to **Off** and the **Exposure Mode** parameter set to **Trigger Width**.

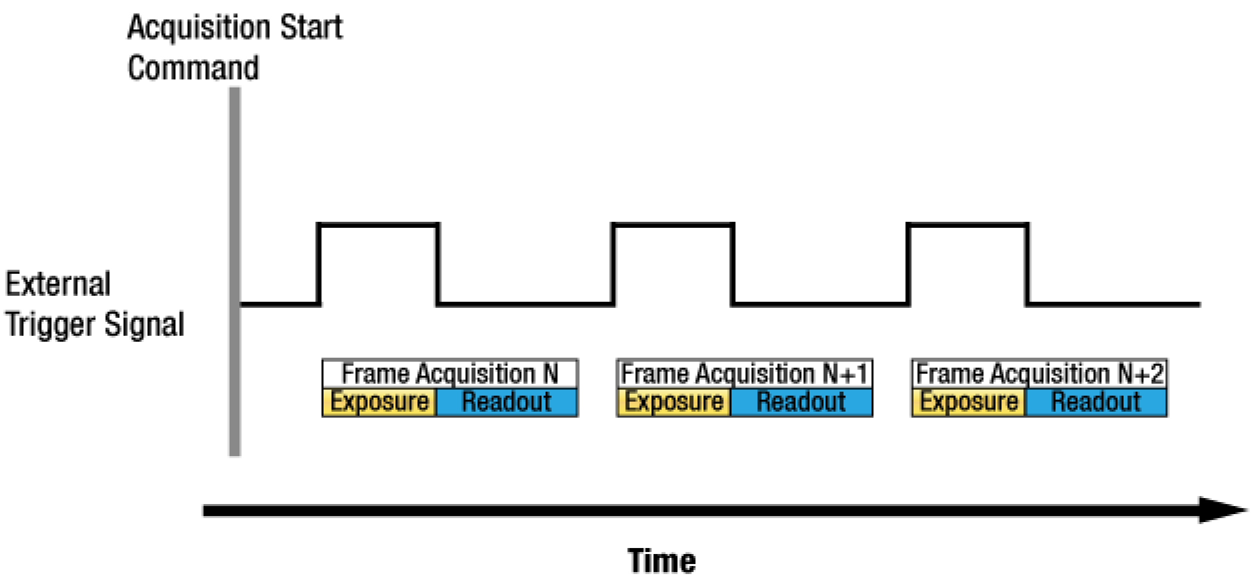


Figure 9.7 Trigger Overlap – Off

In the **Trigger Overlap** – **Readout** mode of operation, the exposure of a new frame begins while the camera is still reading out the sensor data for the previously acquired frame. Figure 9.8 illustrates the **Trigger Overlap** parameter set to **Readout** and the **Exposure Mode** parameter set to **Trigger Width**.

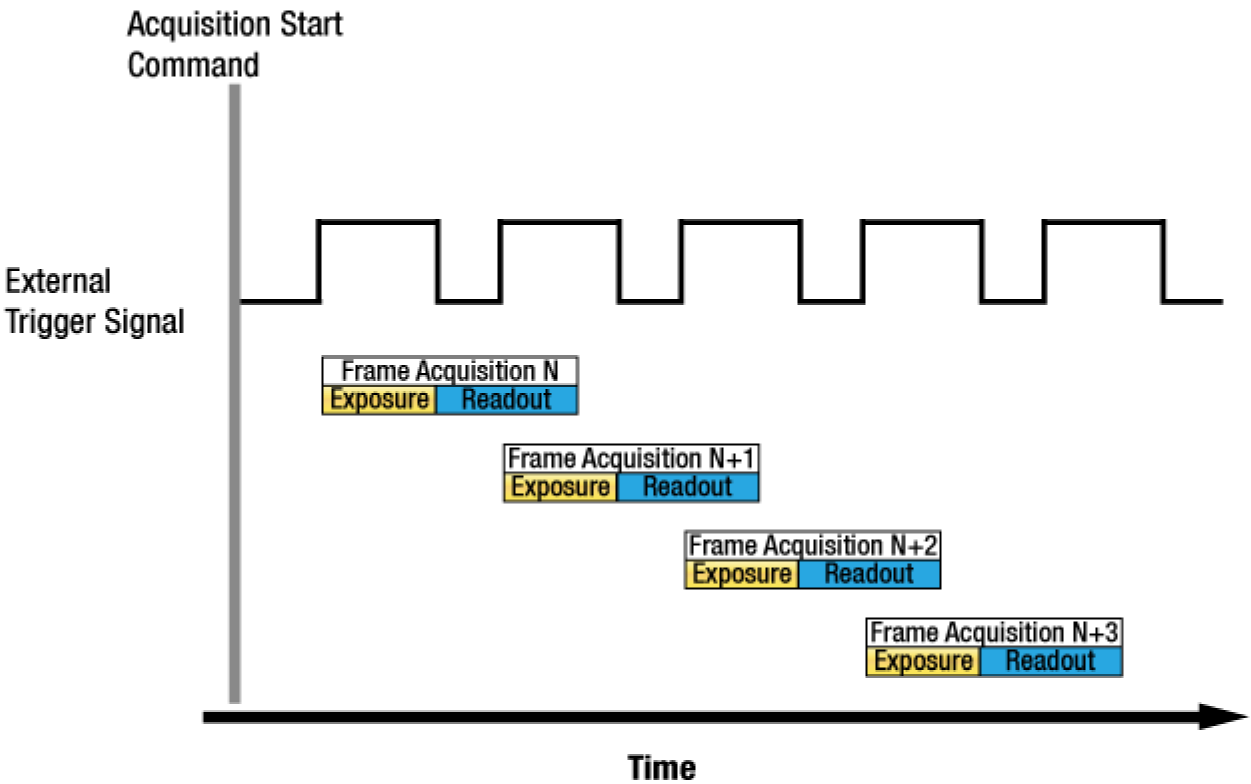


Figure 9.8 Trigger Overlap - Readout

Rather the way that you operate the camera will determine whether the exposures and readouts are overlapped or not.

If we define the "Frame Period" as the time from the start of exposure for one frame acquisition to the start of exposure for the next frame acquisition, then:

- Non-overlapped: Frame Period ≥ Exposure Time + Readout Time
- Overlapped: Frame Period ≤ Exposure Time + Readout Time

Guidelines for Overlapped Exposure

If you will be operating the camera with overlapped exposure, there are two important guidelines to keep in mind:

- You must not begin the exposure time for a new image acquisition while the exposure time of the previous acquisition is in progress.
- You must not end the exposure time of the current image acquisition until readout of the previously acquired image is complete.

When you are operating a camera with overlapped exposure and using an external trigger signal to trigger image acquisition, you could use the camera's Exposure Time parameter settings and timing formulas to calculate when it is safe to begin each new acquisition.

	The exposure must always begin on an interline boundary of the CCD sensor. For this reason, if a trigger signal is applied during the readout process, there might be an Exposure Start Delay up to 1 horizontal line time.

9.6 CCD Real Exposure (Except VQ-310G-M400)

9.6.1 Timed Exposure Mode

When the **Timed** mode is selected, the exposure time is determined by the time interval between the point where an external trigger signal is applied and the point where the t_{pd} (Photodiode Transfer) signal falls.
The camera generates a shutter signal to clear pixels when an external trigger signal is applied. The exposure time begins when the shutter signal falls and continues until the t_{pd} (Photodiode Transfer) signal falls. As Figure 9.9 shows, there is an Exposure Start Delay (refer to Table 9.4) between the rise of the external trigger signal and the rise of the shutter signal. The setting value on the **Exposure Time** parameter is equal to the exposure time, because the t_{sub} value of the shutter signal and Transfer Pulse Offset value (t_{pd}, t_{3p}) are compensated on the exposure time by the camera's logic internally. Therefore, there is no difference between the setting value on the **Exposure Time** parameter and the exposure time. The t_{sub} value and Transfer Pulse Offset value are determined by the CCD sensor used in the camera.

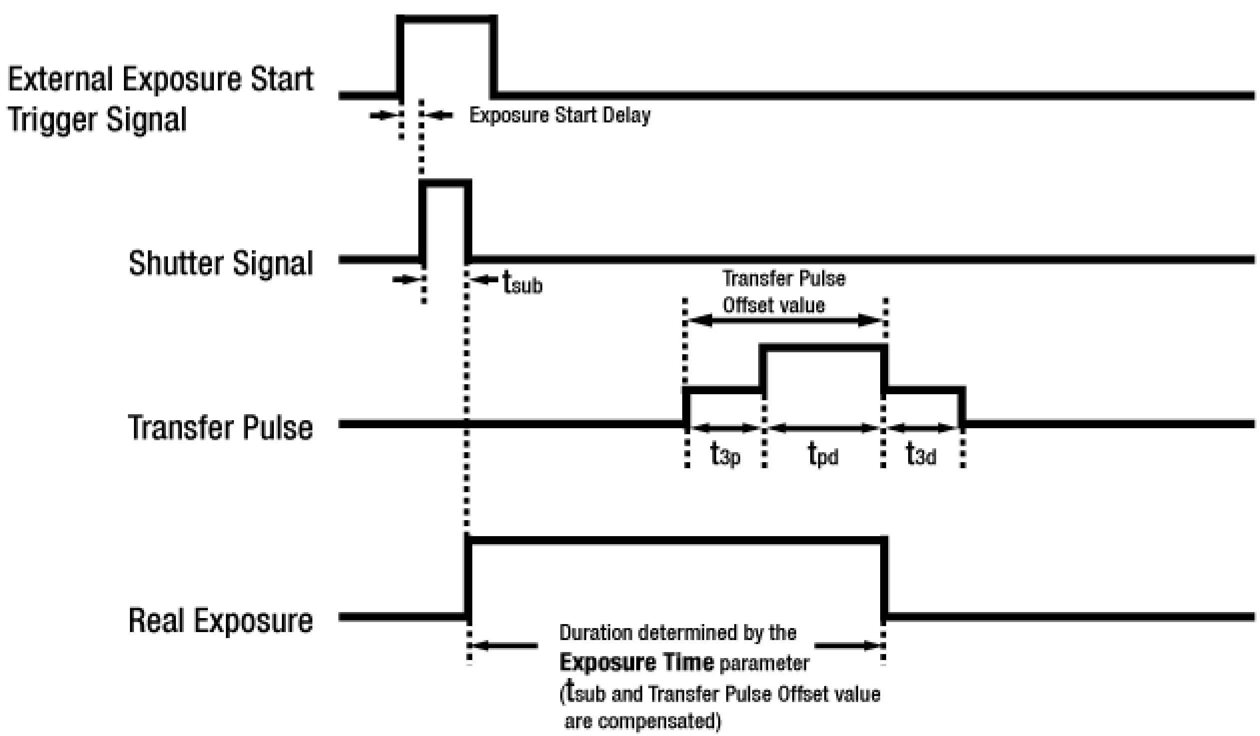


Figure 9.9 Real Exposure with Timed Exposure Mode

9.6.2 Trigger Width Exposure Mode

When the **Trigger Width** mode is selected, the exposure time is controlled by the external trigger signal.
The camera generates a shutter signal to clear pixels when an external trigger signal is applied. The exposure time begins when the shutter signal falls and continues until the t_{pd} (Photodiode Transfer) signal falls. As Figure 9.10 shows, there is an Exposure Start Delay (refer to Table 9.4) between the rise of the external trigger signal and the rise of the shutter signal. There is difference between the width of the external trigger signal and the exposure time as much as the t_{sub} value of the shutter signal and Transfer Pulse Offset value (t_{pd}, t_{3p}).
You can calculate an actual exposure time by using the following formula:

- Exposure Time = Trigger Width + t_{3p} + t_{pd} - t_{sub}

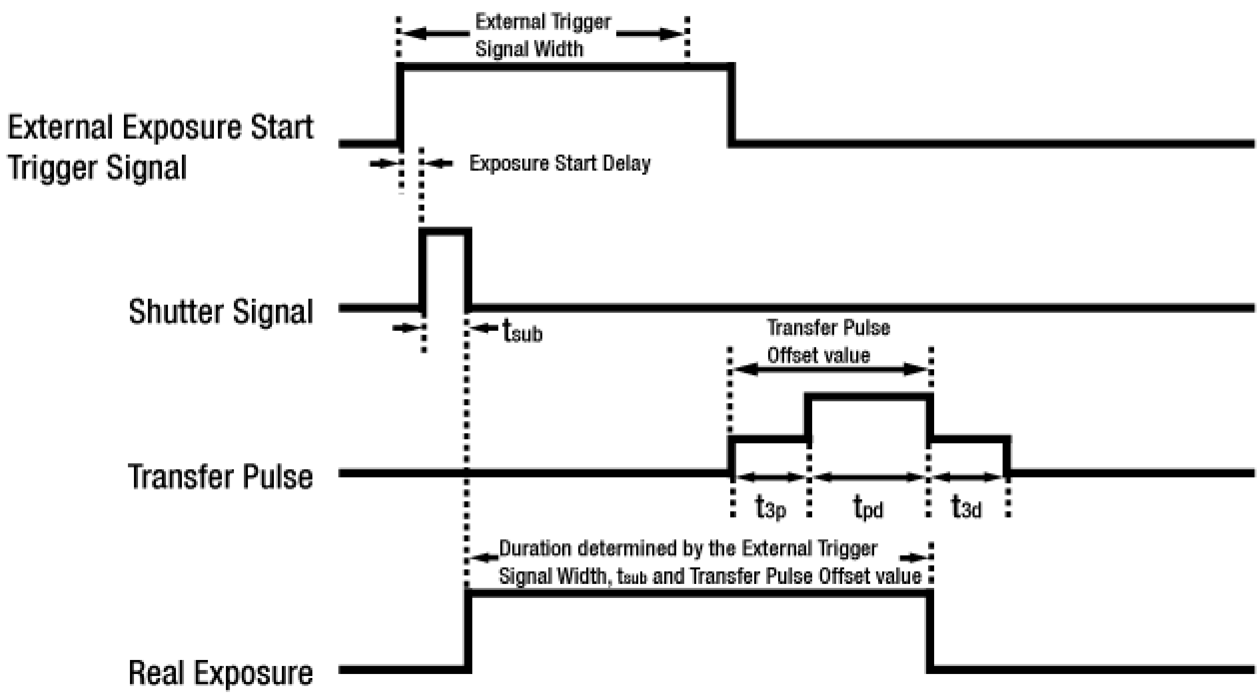


Figure 9.10 Real Exposure with Trigger Width Exposure Mode

The t_{sub} and Transfer Pulse Offset value are determined by the CCD sensor used in the camera.

The following table shows the t_{sub} and Transfer Pulse Offset values for VQ series.

Model	Real Exposure Parameters					Remarks
	t_{sub}	t_{3p}	t_{pd}	t_{3d}	Exposure Start Delay	
VQ-310G-120	1 ㎲	18 ㎲	3 ㎲	–	–	• t_{sub}: Shutter Transfer • t_{3p}: VCCD leading pedestal signal • t_{pd}: Photodiode transfer signal • t_{3d}: VCCD trailing pedestal signal • Exposure Start Delay: Trigger Latency + Trigger Jitter
				–	–	
VQ-1300G	1 ㎲	5 ㎲	3 ㎲	–	–	
				–	–	
VQ-2MG	2 ㎲	25 ㎲	4 ㎲	–	–	
VQ-5MG	2 ㎲	22 ㎲	15 ㎲	–	–	

Table 9.2 Real Exposure Parameters

9.7 CMOS Real Exposure (VQ-310G-M400)

9.7.1 Timed Exposure Mode

In VQ-310G-M400, when you set the **Exposure Mode** to **Timed** or operate the camera in the free run mode, the exposure time for each frame acquisition is determined by the value of the camera's **Exposure Time** parameter. With these settings, the camera will generate trigger signals internally. As soon as the camera detects a trigger signal, the camera will begin a frame exposure. When the exposure time ends, the pixels are being sampled and prepared for readout. This sequence is called the frame overhead time (FOT). Immediately after the FOT, the frame is read out automatically. During the FOT, an additional exposure time will be applied as the offset value shown in the figure below. The setting value on the exposure time is equal to actual exposure time, because the offset value is compensated on the actual exposure time. For example, the exposure time is set to 200 ㎲. The camera will subtract offset value 65 ㎲ from the exposure time setting internally, and thus the actual exposure time will be 200 ㎲ as the user settings. Due to the offset value, the minimum exposure time is limited to 65 ㎲.

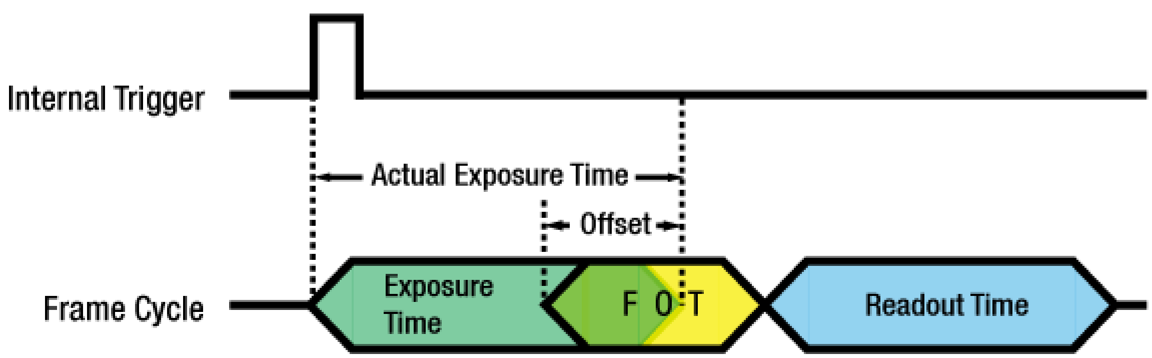


Figure 9.11 Timed Exposure Mode for VQ-310G-M400

Camera Model	Offset Value	Minimum Exposure Time
VQ-310G-M400	65 ㎲	65 ㎲

Table 9.3 Offset Value and Min. Exposure Time for VQ-310G-M400

9.7.2 Trigger Width Exposure Mode

In VQ-310G-M400, when you set the **Exposure Mode** to **Trigger Width**, the exposure time is determined by the way that you manipulate the rise and fall of the external signal (trigger width). As soon as the camera detects an external trigger signal, the camera will begin a frame exposure and an additional exposure time will be applied as the offset value (Table 9.3) shown in the figure below.

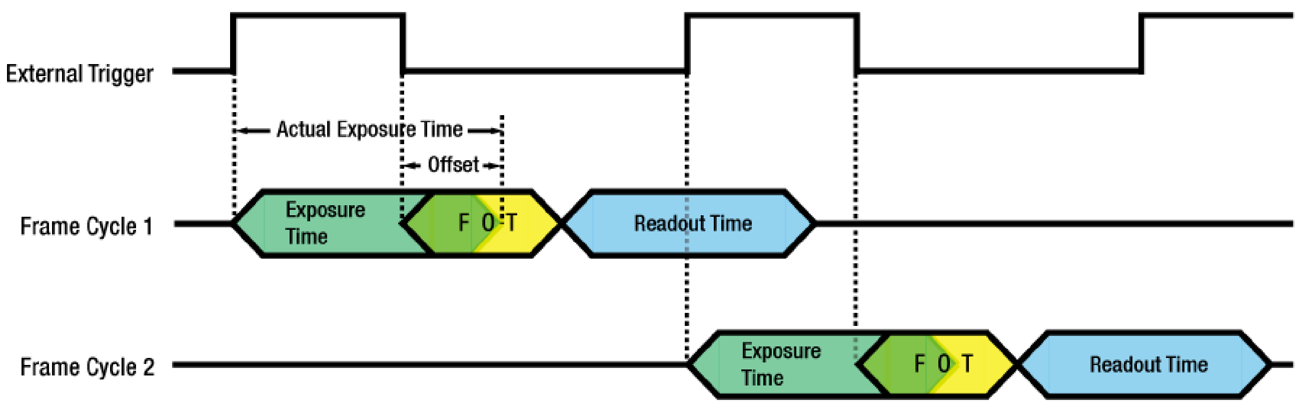


Figure 9.12 Trigger Width Exposure Mode for VQ-310G-M400

9.8 Electronic Shutter Operation

VQ Series is equipped with imaging sensors that have an electronic shutter. There are two types of electronic sensors, i.e. global and rolling. VQ series uses sensors with global shutters.

9.8.1 Global Shutter

When an exposure start trigger signal is applied to the cameras equipped with a global shutter, exposure begins for all lines in the sensor as shown in Figure 9.13. Exposure continues for all lines in the sensor until the programmed exposure time ends or when the exposure start trigger signal ends the exposure time if the camera is using the trigger width exposure mode. At the end of the exposure time, exposure ends for all lines in the sensor. Immediately after the end of exposure, pixel data readout begins and proceeds line by line until all pixel data is read out of the sensor. A main characteristic of a global shutter is that for each frame acquisition, all of the pixels in the sensor start exposing at the same time and all end exposing at the same time. This means that image brightness tends to be more uniform over the entire area of each acquired image, and it helps to minimize problems with acquiring images of object in motion.

The cameras can provide an **Exposure Active** output signal that will go high when the exposure time for a frame acquisition begins and will go low when the exposure time ends.

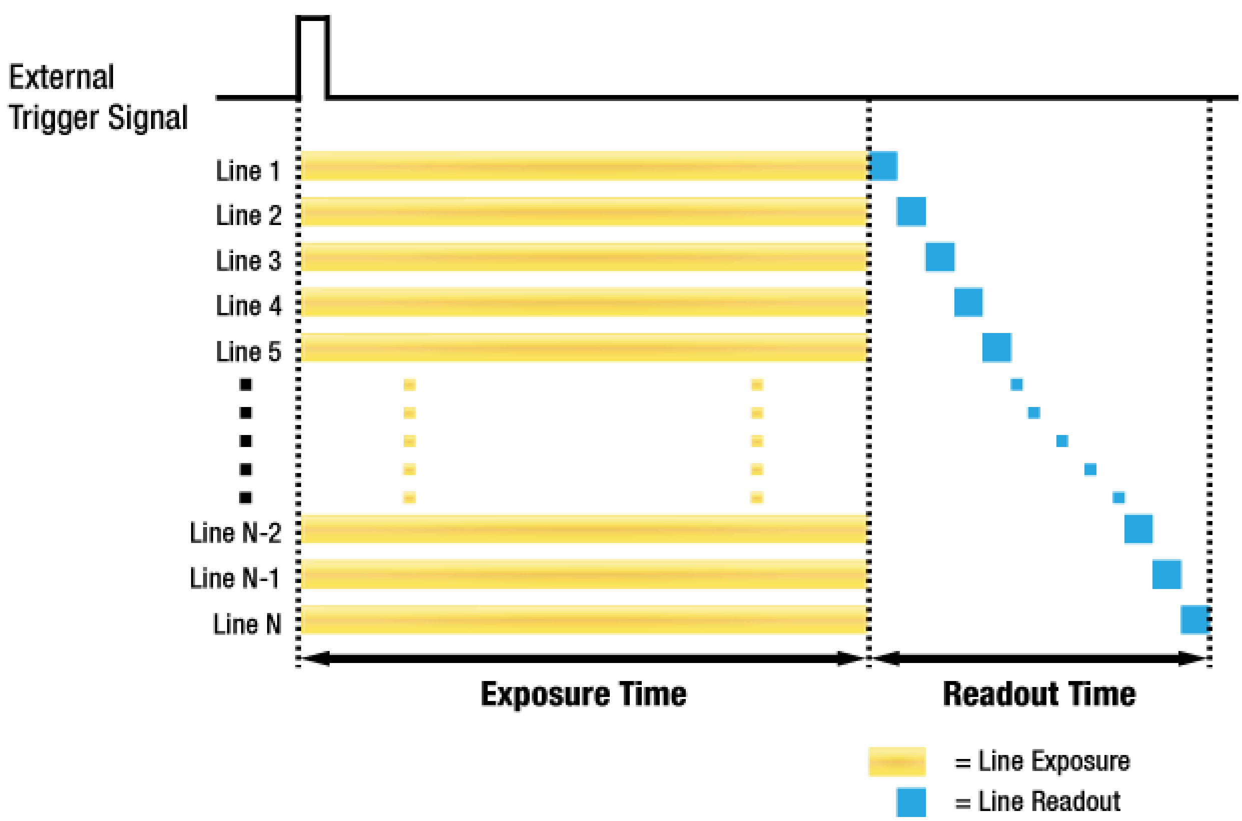


Figure 9.13 Global Shutter

9.9 Acquisition Timing Chart

Figure 9.14 shows a timing chart for frame acquisition and transmission. The chart assumes that exposure is triggered by an externally generated exposure start trigger signal, that the **Trigger Activation** parameter is set to **Rising Edge** and that the **Exposure Mode** parameter is set to **Timed**.

As shown in the figure below, there is a slight delay between the rise of the exposure start trigger signal and the start of exposure. After the exposure time for a frame acquisition is complete, the camera begins reading out the acquired frame data from the imaging sensor into a frame buffer in the camera. When a sufficient amount of frame data has accumulated in the frame buffer, the camera will begin transmitting the data to your computer. This buffering technique avoids the need to exactly synchronize the clock used for sensor readout with the data transmission. The camera will begin transmitting data when it has determined that it can safely do so without over-running or under-running the buffer.

- **Exposure Start Delay**: the amount of time (including trigger jitter and latency) between the point where the trigger signal rises and the point where exposure actually begins
- **Frame Readout time**: the amount of time it takes to read out the frame data from the imaging sensor into the frame buffer
- **Frame Transmission time**: the amount of time it takes to transmit an acquired frame data from the frame buffer in the camera to your computer
- **Transmission Start Delay**: the amount of time between the point where the camera begins reading out the acquired frame data from the sensor and the point where it begins transmitting the acquired frame data from the buffer to your computer

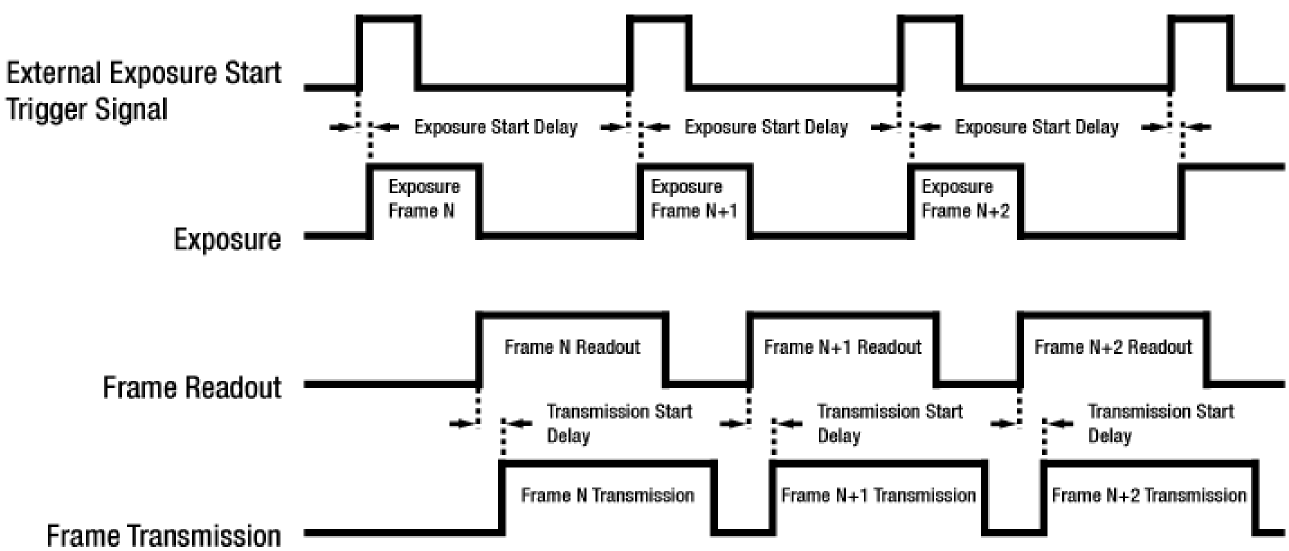


Figure 9.14 Timing Chart (not drawn to scale)

The following table shows Exposure Start Delay for VQ series.

Model	Exposure Mode	Exposure Start Delay
VQ Series (Except VQ-310G-M400)	Timed	6.2 ㎲
	Trigger Width	6.2 ㎲
VQ-310G-M400	Timed	106 ㎲ ≤ Delay ≤ 116 ㎲ (Trigger IN: Active High) 24 ㎲ ≤ Delay ≤ 34 ㎲ (Trigger IN: Active Low)
	Trigger Width	106 ㎲ ≤ Delay ≤ 116 ㎲ (Trigger IN: Active High) 24 ㎲ ≤ Delay ≤ 34 ㎲ (Trigger IN: Active Low)

Table 9.4 Exposure Start Delay

i	The exposure must always begin on an interline boundary of the CCD sensor. For this reason, if a trigger signal is applied during the readout process, there might be an Exposure Start Delay up to 1 horizontal line time.

The transmission time can vary due to the characteristics of the Ethernet network.
And also, the transmission start delay can vary from frame to frame; however, it is very low significance when compared to the transmission time.

9.10 Maximum Allowed Frame Rate

In general, the maximum allowed acquisition frame rate on the camera may be limited by several factors:

- The amount of time that it takes to transmit an acquired frame from the camera to your computer. The amount of time needed to transmit a frame depends on the bandwidth assigned to the camera.
- The **Binning** feature. If binning is enabled, the maximum allowed frame rate will increase.
- The amount of time it takes to read an acquired frame out of the imaging sensor and into the camera's frame buffer. This time varies depending on the setting for the **Height** parameter. Frames with a smaller height take less time to read out of the sensor. The frame height is determined by the camera's **Height** settings (Image Format Control).
- The exposure time for acquired frames. If you use very long exposure times, you can acquire fewer frames per second.

Decreasing the **Height** parameter can increase the maximum allowed frame rate; however the **Width** parameter does not affect the frame rate.

When the camera's **Acquisition Mode** is set to **Single Frame**, the maximum possible acquisition frame rate for a given ROI cannot be achieved. This is true because the camera performs a complete internal setup cycle for each single frame and because it cannot be operated with Trigger Overlap – Readout mode.
To achieve the maximum possible acquisition frame rate, set the **Acquisition Mode** parameter to **Continuous** and the **Trigger Overlap** parameter to **Readout**.

9.10.1 Increasing the Maximum Allowed Frame Rate

You may find that you would like to acquire frames at a rate higher than the maximum allowed with the camera's current settings. In this case, you must adjust one or more of the factors that can influence the maximum allowed frame rate and then check to see if the maximum allowed frame rate has increased:

- The time that it takes to transmit a frame out of the camera is the main limiting factor on the frame rate. You can decrease the frame transmission time (and thus increase the maximum allowed frame rate) by doing one or more of the following:
  - Use an 8 bit pixel data format rather than a 12 bit pixel format. Images with fewer bits per pixel will take less time to transmit.
  - Use a smaller ROI. Decreasing the ROI means that the camera has less data to transmit and therefore the transmission time will decrease.
  - Use binning. When pixels are binned, there is less data to transmit and therefore the transmission time will decrease.
  - Make sure that the Packet Size (GevSCPSPacketSize) parameter is set as high as possible for your system and that the Inter-Packet delay (GevSCPD) parameter is set as low as possible.
- If you are using normal exposure times and you are using the camera at its maximum resolution, your exposure time will not normally restrict the frame rate. However, if you are using long exposure times or small region of interest, it is possible that your exposure time is limiting the maximum allowed frame rate. If you are using a long exposure time or a small ROI, try using a shorter exposure time and see if the maximum allowed frame rate increases. (You may need to compensate for a lower exposure time by using a brighter light source or increasing the opening of your lens aperture.)

	An important thing to keep in mind is a common mistake new camera users frequently make when they are working with exposure time. They will often use a very long exposure time without realizing that this can severely limit the camera's maximum allowed frame rate. As an example, assume that your camera is set to use a 1 second exposure time. In this case, because each frame acquisition will take at least 1 second to be completed, the camera will only be able to acquire a maximum of one frame per second. Even if the VQ-5MG-16 model's nominal maximum frame rate is, for example, 16 frames per second, it will only be able to acquire one frame per second because the exposure time is set much higher than normal.

10 Camera Features

10.1 Image Region of Interest

The Image Region of Interest (ROI) feature allows you to specify a portion of the sensor array. You can acquire only the frame data from the specified portion of the sensor array while preserving the same quality as you acquire a frame from the entire sensor array. With the ROI feature, you can achieve increased frame rates by decreasing the height of the ROI; however, decreasing the width of the ROI does not affect the frame rate.
The ROI is referenced to the top left corner [origin (0, 0)] of the sensor array as follows.

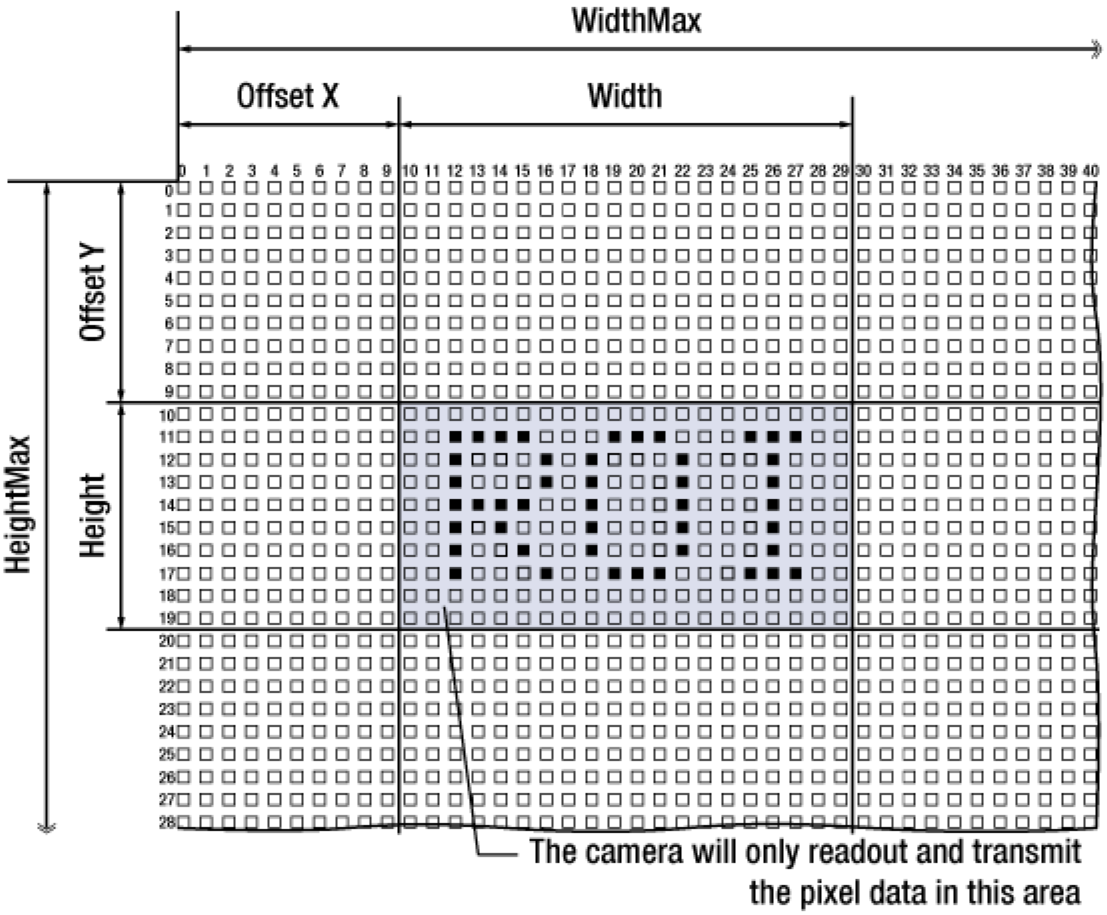


Figure 10.1 Image Region of Interest

The XML parameters related to ROI settings are as follows.

XML Parameters		Value	Description
ImageFormatControl	SensorWidth[a]	-	Effective width of the sensor
	SensorHeight[a]	-	Effective height of the sensor
	WidthMax[b]	-	Maximum allowed width of the image with the current cameras settings
	HeightMax[b]	-	Maximum allowed height of the image with the current camera settings
	Width[c]	-	Current width of the image
	Height[c]	-	Current height of the image
	OffsetX[b, d]	-	Horizontal offset from the origin to the Image ROI
	OffsetY[b, d]	-	Vertical offset from the origin to the Image ROI

The unit for all parameters in this table is pixel
a: Read only. User cannot change the value
b: Changes and updates according to the Binning settings
c: User configurable parameters for settings ROI
d: User configurable parameters for setting the origin of the ROI

Table 10.1 XML parameters related to ROI

You can change the size of ROI by setting the **Width** and **Height** parameters. And also, you can change the position of the ROI origin by setting the **Offset X** and **Offset Y** parameters.
Make sure that the **Width + Offset X** value is less than the **Width Max** value, and the **Height + Offset Y** value is less than the **Height Max** value. You must set the size of the ROI first, and then set the Offset values since the **Width** and **Height** parameters are set to its maximum value by default.
The **Width** parameter must be set to a multiple of 4, and the Height parameter must be set to a value greater than the minimum Vertical ROI size shown in the table 10.2. The **Width Max** and **Height Max** parameters will be changed and updated depending on the **Binning Horizontal** and **Binning Vertical** parameter settings respectively. And also, the **Width**, **Height**, **Offset X** and **Offset Y** parameters will be updated depending on the **Binning Horizontal** and **Binning Vertical** parameter settings respectively.
ROI Size updated according to the Binning settings may not be restored to its original value. For example, if you set the **Binning Horizontal** parameter to **×3** with **500 Width**, the **Width** parameter will be updated to **166** automatically. Then, if you set the **Width** parameter to **166** and the **Binning Horizontal** parameter to **×1**, the **Width** parameter will be **498** (166 × 3). If you want to restore the **Width** to its original value, you can set the **Width** to **500** manually.

The approximate maximum frame rate depending on the change of Vertical ROI can be obtained as shown in the following expression.

```
1 or 2 Channel Mode:
Frame Rate (fps) = 1000000 / [TVCCD + TRF × (VSIZE − VROI) + (VROI × TL)]
```

$$\text{Frame Rate (fps)} = 1000000 / [T_{VCCD} + T_{RF} \times (V_{SIZE} - V_{ROI}) + (V_{ROI} \times T_L)]$$

T_{VCCD}	: the amount of time required to transmit electric charges accumulated on the pixels to Vertical Register
T_{RF}	: the amount of time required for 1 row flush
V_{SIZE}	: the number of Vertical Line of CCD
T_L	: the amount of time required for transmission of one line
V_{ROI}	: size of the Vertical ROI

The available minimum value of T_{VCCD}, T_{RF}, V_{SIZE}, T_L and V_{ROI} may vary depending on the camera model. The values of each item are shown below.

VQ Series	VQ-310G-120†	VQ-1300G-30†	VQ-2MG-20†	VQ-5MG-16‡
T_{VCCD}	25 ㎲	31.1 ㎲	41.2 ㎲	39 ㎲
T_L (1 channel)	16.8 ㎲	34.4 ㎲	40.4 ㎲	-
T_L (2 channel)	-	-	-	30.3 ㎲
T_{RF}	2.6 ㎲	5.0 ㎲	6.1 ㎲	9.1 ㎲
V_{SIZE}	488 Lines	960 Lines	1232 Lines	2056 Lines
Minimum Vertical ROI Size	60 Lines	120 Lines	154 Lines	256 Lines

† Based on Pixel Clock 50 ㎒ (**VQ-310G-120, 1300G-30 and 2MG-20**)

‡ Based on Pixel Clock 60 ㎒ (**VQ-5MG-16**)

Table 10.2 Timing Value for VQ Series

In VQ-310G-M400, the approximate maximum frame rate depending on the change of Vertical ROI can be obtained as shown in the following expression.

Frame Rate (fps) = $1 / [FOT + (T_L \times V_{ROI}/2)]$

FOT : Frame Overhead Time
T_L : 1 line read time
V_{ROI} : size of the Vertical ROI

VQ Series	VQ-310G-M400
FOT	116.7 ㎲
T_L	9.73 ㎲
V_{SIZE}	480 Lines
Minimum Vertical ROI Size	2 Lines

Table 10.3 Timing Value for VQ-310G-M400

The following figure shows frame rate for each camera model depending on Vertical ROI changes.

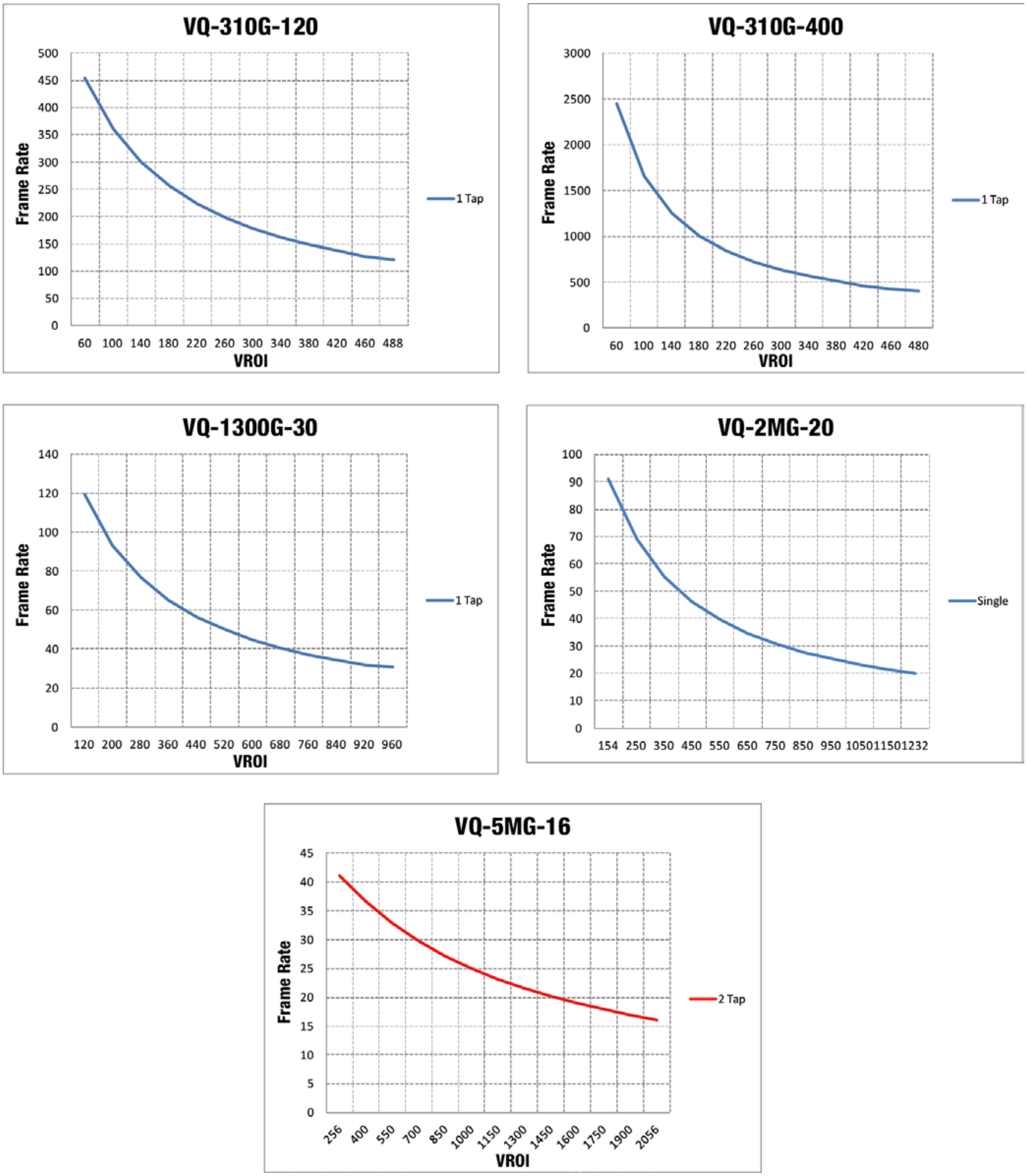


Figure 10.2 Frame Rate by Vertical ROI changes

10.2 Binning (Except VQ-310G-M400)

Binning has the effects of increasing the level value and decreasing resolution by summing the values of the adjacent pixels and sending them as one pixel.
The XML parameters related to Binning are as follows.

XML Parameters		Value	Description
ImageFormatControl	BinningHorizontal	×1, ×2, ×3, ×4	Number of horizontal pixels to combine together
	BinningVertical	×1, ×2, ×3, ×4	Number of vertical pixels to combine together

Table 10.4 XML Parameters related to Binning

For example, if you set 2 × 2 binning as shown in the figure below, four pixels will be summed into one pixel. Then, the effective maximum resolution of the sensor is reduced to 1/2. The **Width Max** and **Height Max** parameters, indicating the maximum allowed resolution of the image with the current camera settings, will be updated depending on the binning settings. And also, the **Width**, **Height**, **Offset X** and **Offset Y** parameters will be updated depending on the binning settings. You can verify the current resolution through the **Width** and **Height** parameters.
Since vertical binning is processed in the internal register of CCD, the frame rate will be increased and SNR will be improved because the number of the readout process is reduced. However, the horizontal binning does not affect the frame rate and SNR because it is processed in the FPGA. The brightness will be increased about four times because four pixels are summed as one.

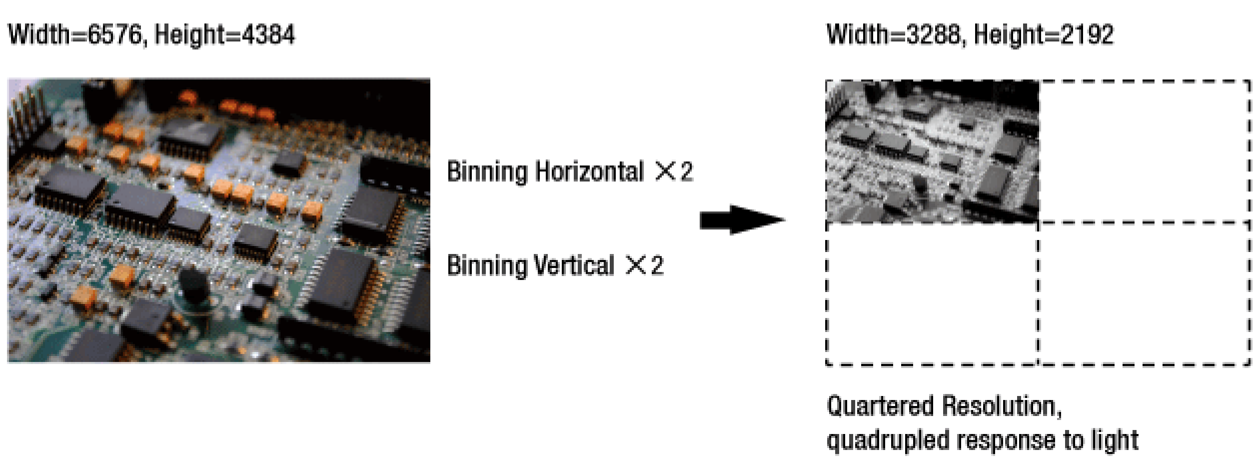


Figure 10.3 Binning

VQ series supports ×1, ×2, ×3, ×4 binning factors for both vertical and horizontal direction independently.

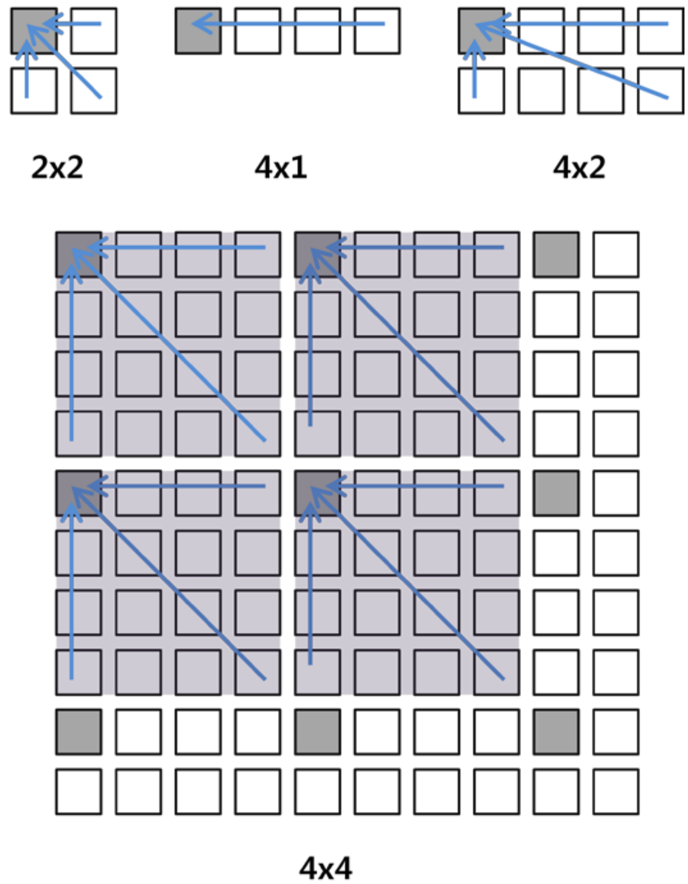


Figure 10.4 Binning factor

- Even if the binning is performed on the color camera, the resulting image will be monochrome.
- The odd number of binning factor (×3) does not supported on the color camera due to the characteristics of Bayer pattern.

10.3 Sensor Tap Settings

VQ-5MG-16 model uses two taps sensor digitization in which two (left and right) video amplifiers are used to output the charges moved to the horizontal register during reading out the accumulated charges. Charges from the left half of the sensor are shifted towards the Video L and charges from the right half of the sensor are shifted towards Video R.

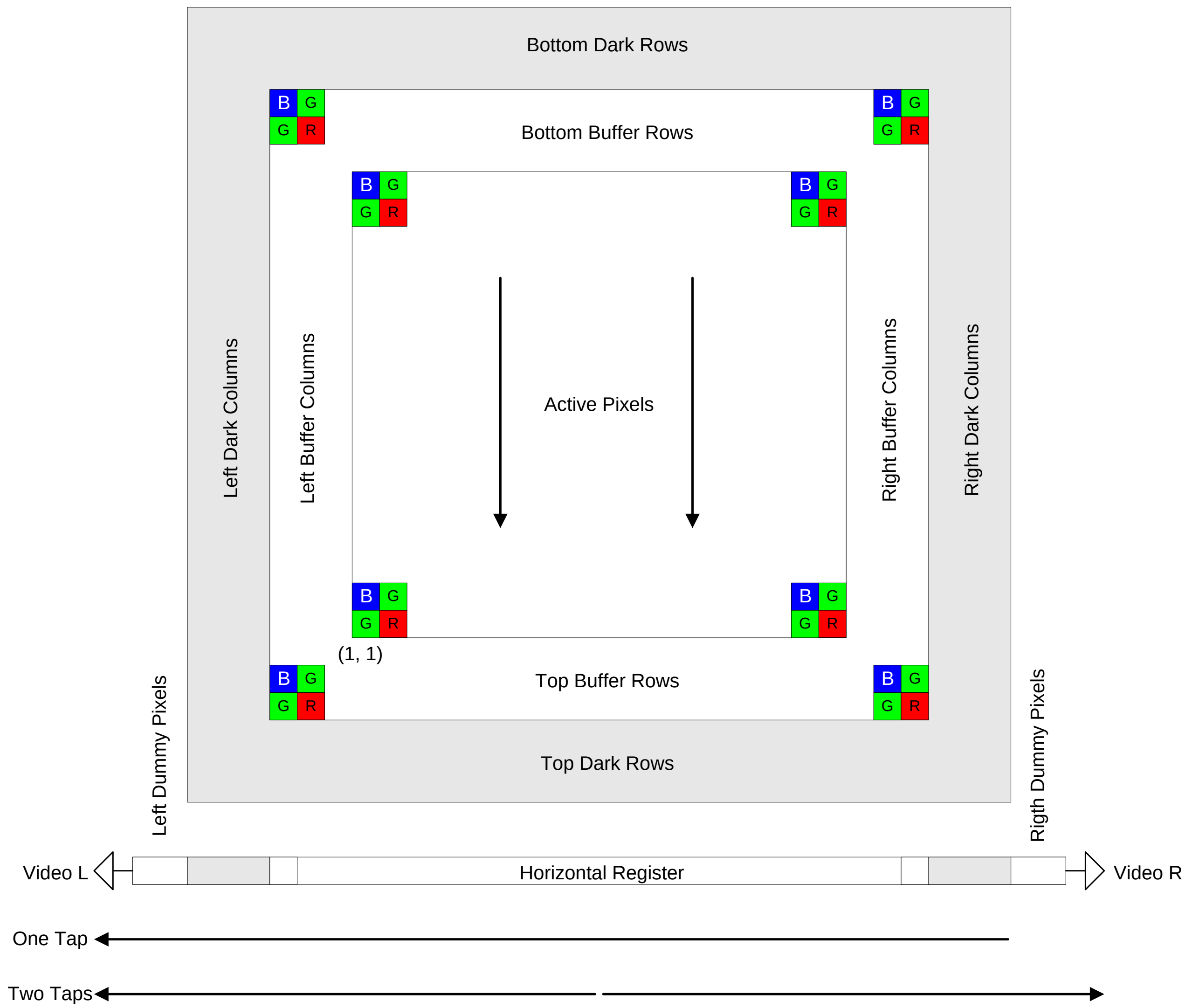


Figure 10.5 Two Taps Sensor Digitization

XML parameters related to Sensor Tap Settings are as follows.

XML Parameters		Value	Description
ImageFormatControl	SensorDigitizationTaps	One	Set the Sensor Readout mode to 1 tap
		Two	Set the Sensor Readout mode to 2 tap

Table 10.5 XML Parameter related to Sensor Tap settings

Both VQ-310G-120, VQ-1300G-30 and VQ-2MG-20 use one tap sensor digitization in which only the left video amplifier (Video L) will be used to output the video data as shown in the Figure 10.6. VQ-5MG-16 uses two taps sensor digitization in which both Video L and Video R will be used to output the video data as shown in the Figure 10.7. When LVDS signals converted from the video data through ADC are transmitted to FPGA, the signal data will be stored in the line buffer of FPGA until the transmission of one horizontal line is completed. Figure 10.9 and 10.10 show the structure which reorders and stores one line video data in the line buffer of FPGA according to the one tap and two taps settings. In VQ-310G-M400, its CMOS image sensor performs ADC conversion directly. As shown in the Figure 10.8, the sensor will output image data through four channels and then FPGA will reorder image data in one line using the line buffer.
After completing one line transmission, the data goes through image processing. Then, the data will be reordered according to the **Pixel Format** parameter setting value and stored in the frame buffer.

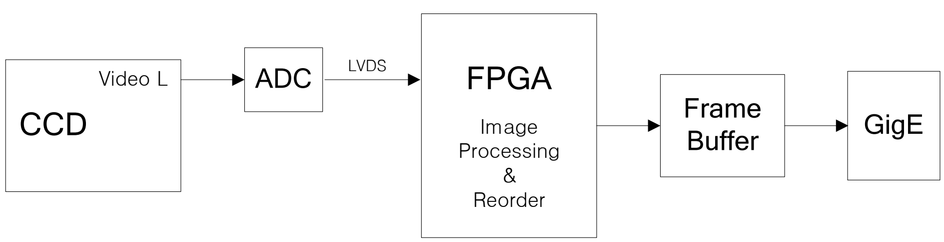


Figure 10.6 1Tap Image Data Flow

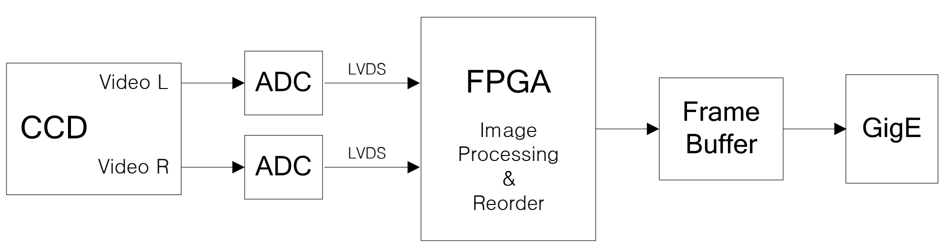


Figure 10.7 2Taps Image Data Flow

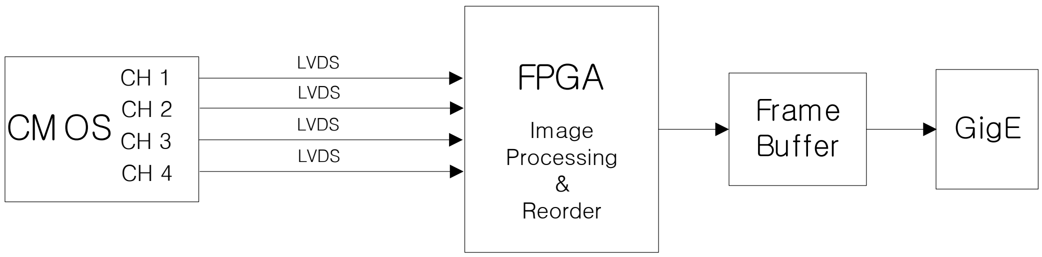


Figure 10.8 VQ-310G-M400 Image Data Flow

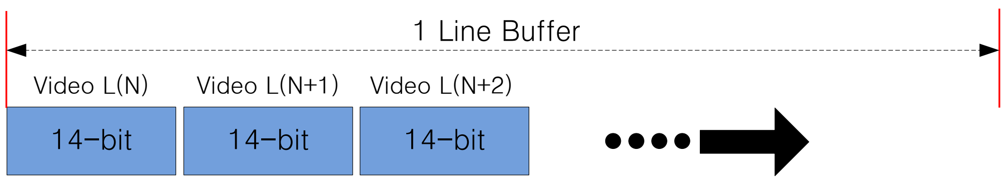


Figure 10.9 1 Tap Reorder

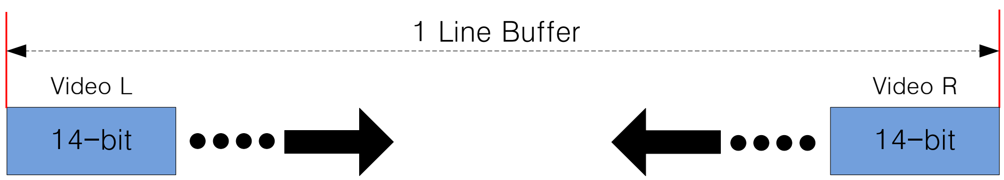


Figure 10.10 2 Tap Reorder

The LVDS video data converted in ADC are 14 bits, however the camera outputs 12 bits video data. The noise performance will be improved on the output image by removing the 2 least significant bits.

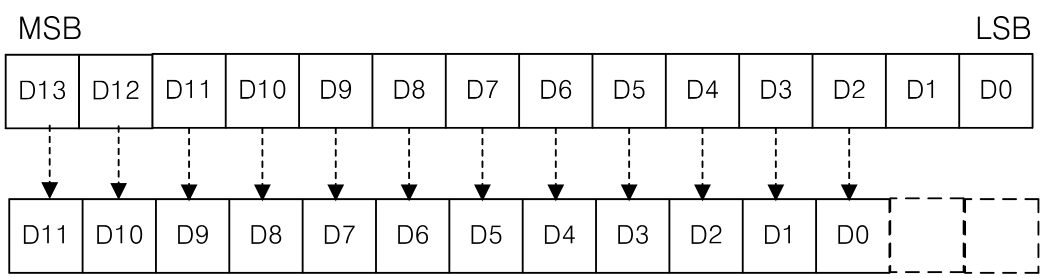


Figure 10.11 12bit Conversion

- VQ-310G-120, VQ-1300G-30 and VQ-2MG-20 support only one tap sensor digitization.
- VQ-5MG-16 supports only two taps sensor digitization.

10.4 Pixel Format

The internal processing of image data is performed in 12 bits. Then, the camera can output the data in 8, 10 or 12 bits. When the camera outputs the image data in 8 bits or 10 bits, the 4 or 2 least significant bits will be truncated accordingly.

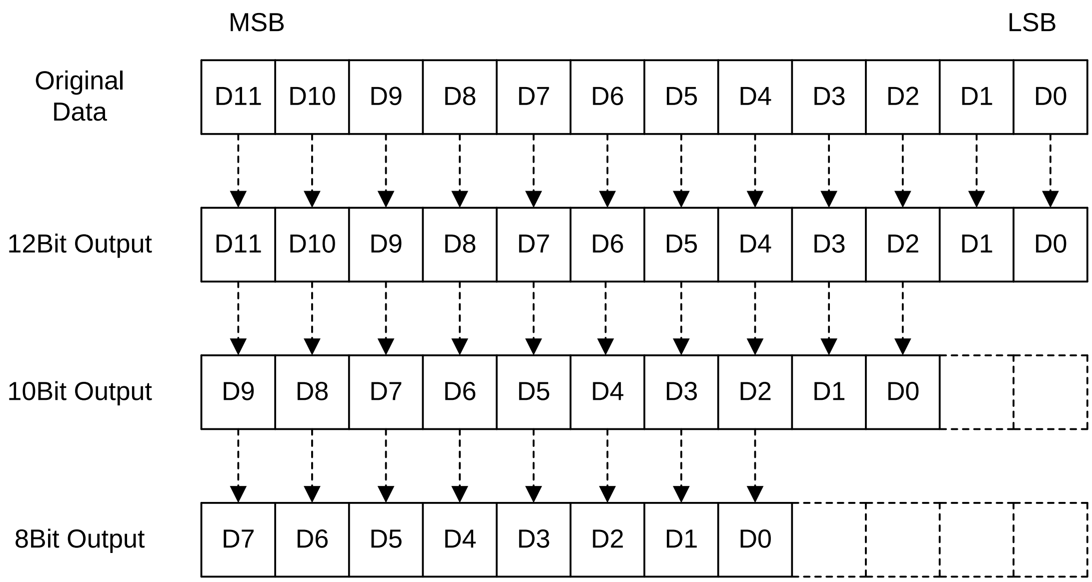


Figure 10.12 Pixel Format

The image data converted to 8, 10 or 12 bits support various pixel data format depending on the camera model. The pixel data will be reordered in FPGA according to the **Pixel Format** setting value. Then, it will be stored in the frame buffer before output. XML parameter related to the Pixel Format is as follows.

XML Parameters		Description
ImageFormatControl	PixelFormat	Set the pixel format supported by the device

Table 10.6 XML Parameter related to Pixel Format

The supported pixel formats for monochrome and color cameras are as follows.

Mono Sensor	Color Sensor
• Mono 8 • Mono 10 • Mono 10 Packed • Mono 12 • Mono 12 Packed	• Mono 8 • Mono 10 • Mono 10 Packed • Mono 12 • Mono 12 Packed • Bayer BG 8 • Bayer BG 10 • Bayer BG 10 Packed • Bayer BG 12 • Bayer BG 12 Packed • Bayer RG 8 • Bayer RG 10 • Bayer RG 10 Packed • Bayer RG 12 • Bayer RG 12 Packed • YUV422 Packed • YUV422 (YUYV) Packed

Table 10.7 Pixel Data Format Value

10.4.1 Mono 8

With the camera set to **Mono 8**, the pixel data output is 8 bit monochrome, unsigned char and unpacked type. This type is stored in a byte unit when 8 bit pixel data are stored in the frame buffer.

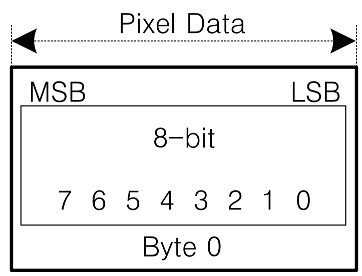


Figure 10.13 Mono 8 Format

10.4.2 Mono 10

With the camera set to **Mono 10**, the pixel data output is 10 bit monochrome, unsigned char and unpacked type. This type is divided into two bytes when 10 bit pixel data are stored in the frame buffer. 8 bits of pixel data will be stored in Byte 0, 2 bits of pixel data will be stored in Byte 1, and the rest 6 bits will not be used.

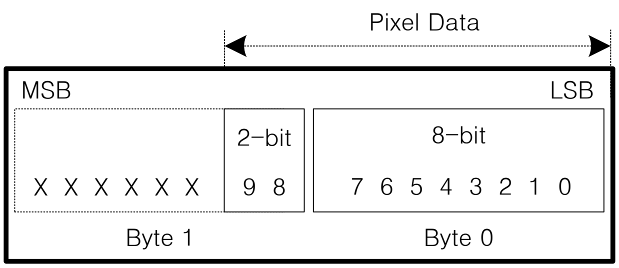


Figure 10.14 Mono 10 Format

10.4.3 Mono 10 Packed

With the camera set to **Mono 10 Packed**, the pixel data output is 10 bit monochrome, unsigned char and GigE Vision-specific packed type.

This type is divided into three bytes when 20 bit pixel data are stored in the frame buffer. 8 bits of pixel data 0 will be stored in Byte 0 and the rest 2 bits will be stored in Byte 1. Pixel Data 1 will be stored in Byte 2 and the rest 2 bits will be stored in Byte 1.

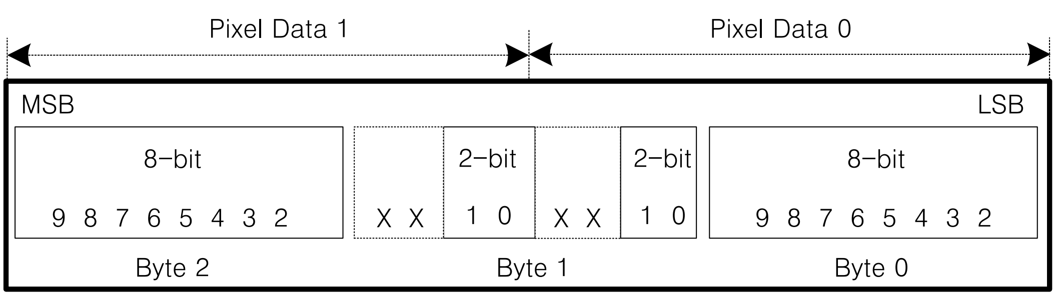


Figure 10.15 Mono 10 Packed Format

10.4.4 Mono 12

With the camera set to **Mono 12**, the pixel data output is 12 bit monochrome, unsigned and unpacked type.

This type is divided into two bytes when 12 bit pixel data are stored in the frame buffer. 8 bits of pixel data will be stored in Byte 0 and the rest 4 bits will be stored in Byte 1. The rest 4 bits of Byte 1 will not be used.

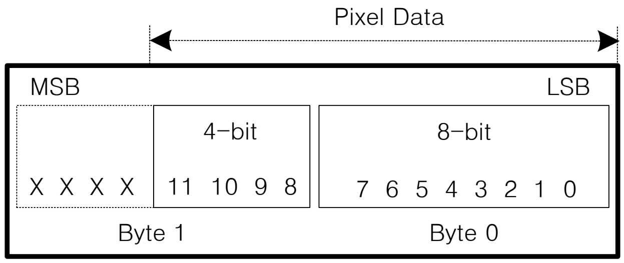


Figure 10.16 Mono 12 Format

10.4.5 Mono 12 Packed

With the camera set to **Mono 12 Packed**, the pixel data output is 12 bit monochrome, unsigned and GigE Vision-specific packed type.

This type will be divided into three bytes when 24 bit pixel data are stored in the frame buffer.

8 bits of pixel data 0 will be stored in Byte 0 and the rest 4 bits will be stored in Byte 1. 8 bits of pixel data 1 will be stored in Byte 2 and the rest 4 bits will be stored in Byte 1.

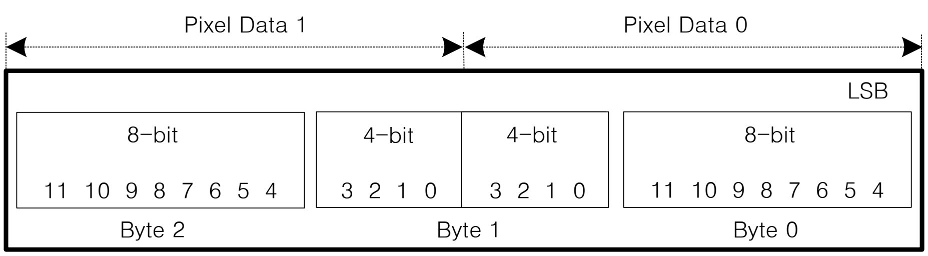


Figure 10.17 Mono 12 Packed Format

10.4.6 Bayer Formats

When you set the **Pixel Format** parameter to any **Bayer Format** in the color camera, the bits of pixel data will be reordered to bytes, and then will be stored in the frame buffer in the same way as **Mono Format**.

For example, if you set the **Pixel Format** parameter to **Bayer GR 10 Packed**, the pixel data will be reordered and stored in the frame buffer as shown in the Figure 10.17. 10 least significant bits of green data will be stored in Byte 0 and Byte 1, and 10 most significant bits of red data will be stored in Byte 2 and Byte 1. The bit order is shown in the first figure below. After saving 1 - horizontal line of G-R pattern pixel data, 2 – horizontal line of B-G pattern pixel data will be stored as shown in the second figure below. G-R pattern (Horizontal Direction) and B-G pattern (Horizontal Direction) pixel data will be stored repeatedly as a line (Vertical Direction).

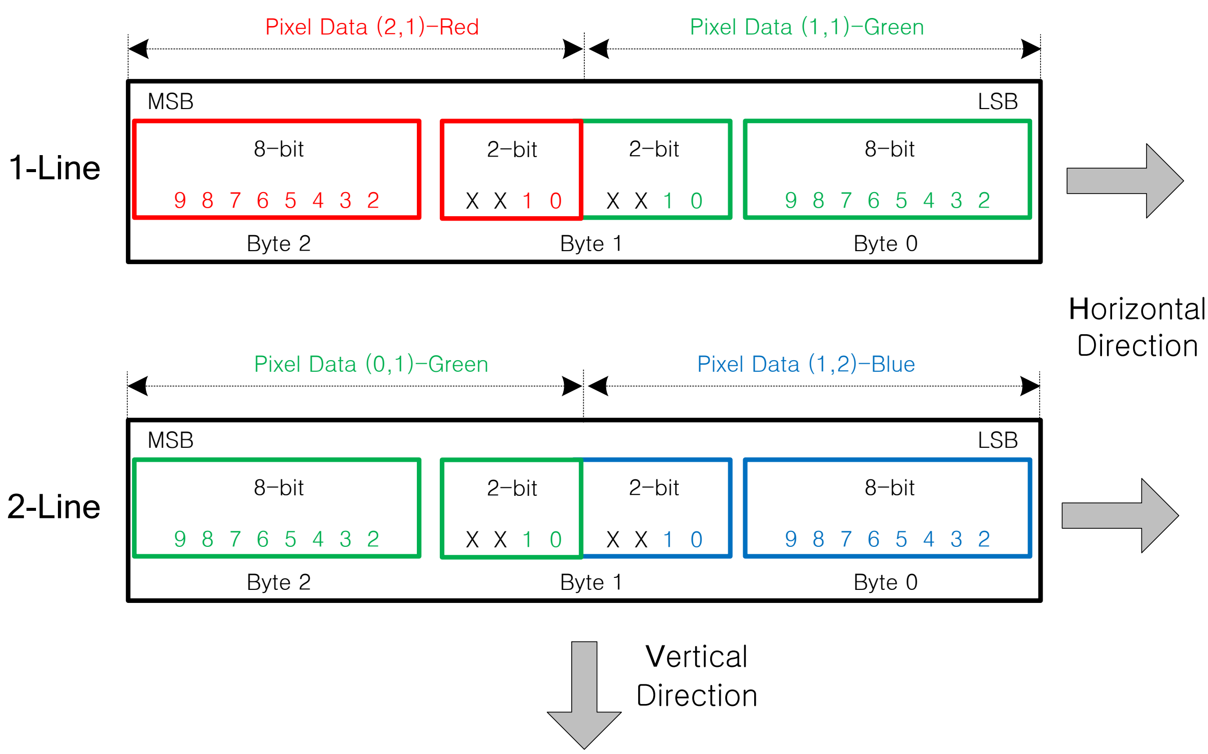


Figure 10.18 Bayer Format

10.4.7 YUV Formats

All VQ color cameras except VQ-5MG-16 can output pixel data in YUV422 Packed format or in YUV422 (YUYV) Packed format. When a color camera is set for either of these formats, each pixel in the acquired image goes through a two step conversion process. In the first step of the process, a demosaicing algorithm is performed to get RGB data for each pixel. The second step of the process is to convert the RGB information to the YUV color model. The conversion algorithm uses the following formulas:

$$Y = 0.299\,R + 0.587\,G + 0.114\,B$$
$$U = -0.169\,R - 0.331\,G + 0.499\,B$$
$$V = 0.499\,R - 0.418\,G - 0.0813\,B$$

	The values for U and V normally range from -128 to +127. Because the camera transfers U and V values with unsigned integers, 128 is added to each U and V value before the values are transferred from the camera. This process allows the values to be transferred on a scale that ranges from 0 to 255.

YUV422 Packed

The following table shows how the pixel data for an acquired frame will be ordered in the image buffer in your computer when the **Pixel Format** parameter is set to **YUV422 Packed** on a color camera.

- B_0 = the first byte in the buffer
- B_n = the last byte in the buffer
- P_0 = the first pixel transmitted by the camera
- P_m = the last pixel transmitted by the camera

Byte	Data
B_0	U value for P_0
B_1	Y value for P_0
B_2	V value for P_0
B_3	Y value for P_1
B_4	U value for P_2
B_5	Y value for P_2
B_6	V value for P_2
B_7	Y value for P_3
B_8	U value for P_4
B_9	Y value for P_4
B_{10}	V value for P_4
•	•
•	•
•	•
B_{n-3}	U value for P_{m-1}
B_{n-2}	Y value for P_{m-1}
B_{n-1}	V value for P_{m-1}
B_n	Y value for P_m

Table 10.8 YUV422 Packed Format

YUV422 (YUYV) Packed

The following table shows how the pixel data for an acquired frame will be ordered in the image buffer in your computer when the **Pixel Format** parameter is set to **YUV422 (YUYV) Packed** on a color camera.

- B_0 = the first byte in the buffer
- B_n = the last byte in the buffer
- P_0 = the first pixel transmitted by the camera
- P_m = the last pixel transmitted by the camera

Byte	Data
B_0	Y value for P_0
B_1	U value for P_0
B_2	Y value for P_1
B_3	V value for P_0
B_4	Y value for P_2
B_5	U value for P_2
B_6	Y value for P_3
B_7	V value for P_2
B_8	Y value for P_4
B_9	U value for P_4
B_{10}	Y value for P_5
B_{11}	V value for P_4
•	•
•	•
•	•
B_{n-3}	Y value for P_{m-1}
B_{n-2}	U value for P_{m-1}
B_{n-1}	Y value for P_m
B_n	V value for P_{m-1}

Table 10.9 YUV422 (YUYV) Packed Format

10.5 Stream Hold

VQ camera provides **Stream Hold** feature for controlling the transmission of data.
Normally, the camera transmits frame data to the host computer immediately after completing the exposure. Enabling the **Stream Hold** feature delays the transmission of data, storing it in the camera's volatile memory until the **Stream Hold** feature is disabled.
This feature is especially useful to prevent flooding in Gigabit Ethernet network where multiple cameras are connected to a single host computer and capture a single event. Using the **Stream Hold** feature, each camera will hold the image data until the camera's **Stream Hold** feature is disabled. VQ camera provides 64 MB on-board memory for the **Stream Hold** feature. The **Stream Hold** feature does not allow you to select which frame will be released to the host computer. When the **Stream Hold** feature is disabled, the stored frame data will be released to the host computer. For more information, refer to the application note about stream hold.

XML Parameters		Value	Description
TransportLayerControl	StreamHold	On	Delay the transmission of frame data and store them in the frame buffer.
		Off	Release the stored frame data to the host computer.
	FrameCapacity	-	• Display the maximum number of frames that you can store in the frame buffer • The maximum number of frames will vary depending on the Image ROI and pixel format settings. • With the **Stream Hold** feature set to **On**, the newly acquired frame will be ignored after saving the maximum number of frames.

Table 10.10 XML Parameters related to Stream Hold feature

10.6 Inter-Packet Delay

VQ camera provides the Inter-packet delay feature to set the delay in ticks between the packets transmitted by the camera.

Packet Size

The **GevSCPSPacketSize** parameter sets the size of the packets that the camera will use when it sends the data via the selected stream channel. This parameter should always be set to the maximum size that your network components (Ethernet Adapter) can handle.

Setting the Delay between Packets

The **GevSCPD** parameter sets the delay in ticks between the packets transmitted from the camera. Increasing the delay will decrease the camera's effective data transmission rate and will thus decrease the network bandwidth used by the camera.
In the VQ camera, one tick is 8 ㎱. To check the tick frequency, read the **GevTimestampTickFrequency** parameter value.
In case of multiple cameras or other devices working on the same physical network, it might be desirable to send the packets of a camera's streaming channel with a certain inter-packet delay in order to allow multiple cameras or devices to share a given network bandwidth.

XML Parameters		Value	Description
TransportLayerControl	GevSCPSPacketSize	576~16,000 Bytes	Set the packet size (The maximum value may vary depending on the Ethernet Adapter.).
	GevSCPD	0~ 2141483647	Set the delay in ticks (one tick = 8 ㎱) between packets.

Table 10.11 XML Parameters related to Inter-Packet Delay

10.7 Data ROI

The **Exposure Auto** (Except VQ-5MG-16) and **Balance White Auto** features use the pixel data from a Data Region of Interest (ROI) to adjust the related parameters.

XML parameters related to data ROI are as follows.

<table>
<tr><th colspan="2">XML Parameters</th><th>Value</th><th>Description</th></tr>
<tr><td rowspan="6">DataRoiControl</td><td rowspan="2">RoiSelector</td><td>AE</td><td>• Select a Data ROI used for Auto Exposure
• All models except VQ-5MG-16</td></tr>
<tr><td>AWB</td><td>• Select a Data ROI used for Auto White Balance
• Only available on color cameras</td></tr>
<tr><td>RoiOffsetX</td><td>-</td><td>X coordinate of start point ROI</td></tr>
<tr><td>RoiOffsetY</td><td>-</td><td>Y coordinate of start point ROI</td></tr>
<tr><td>RoiWidth</td><td>-</td><td>Width of ROI</td></tr>
<tr><td>RoiHeight</td><td>-</td><td>Height of ROI</td></tr>
</table>

Table 10.12 XML Parameters related to Data ROI

Only the pixel data from the area of overlap between the data ROI by your settings and the Image ROI will be effective if you use Image ROI and Data ROI at the same time. The effective ROI is determined as shown in the figure below.

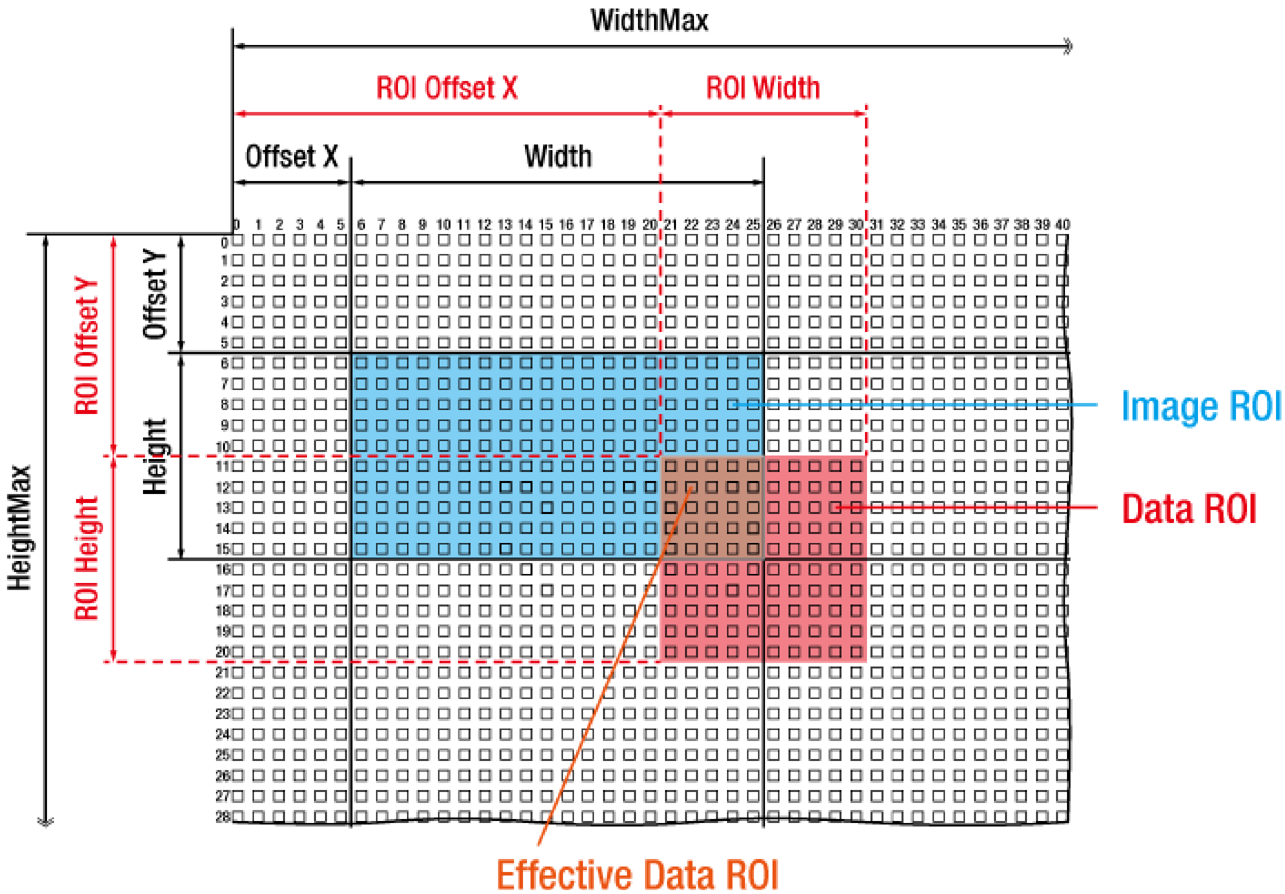


Figure 10.19　Effective Data ROI

10.8 Exposure Auto and Gain Auto (Except VQ-5MG-16)

The **Exposure Auto** feature automatically adjusts the **Exposure Time** parameter until the grey level for the pixels in the given Data ROI reaches an **Exposure Auto Target Level** value set by the user.

The **Exposure Auto** feature in VQ GigE series uses iterative algorithm which repeatedly calculates the previous exposure values until it gets new exposure value. Note that the camera needs up to 30 frames to complete the **Exposure Auto** feature.

The **Exposure Auto** feature is not available if the **Exposure Mode** parameter is set to **Trigger Width**.

The **Exposure Auto** and **Gain Auto** features can be used at the same time and operated in the **Off**, **Once** and **Continuous** modes of operation. If you use two features at the same time, the camera will adjust the value of **Exposure Time** followed by **Digital Gain**.

When the **Exposure Auto** or **Gain Auto** feature is set to **Once**, the parameter values are automatically adjusted until the related parameter value reaches the target value. After the automatic parameter value adjustment is complete, the feature will be set to **Off**. When the auto feature is set to **Continuous**, the camera adjusts **Exposure Time** or **Digital Gain** parameter to reach the target value every time the lighting conditions change.

You can set the **Exposure Auto Tolerance** parameter to adjust the sensitivity of the **Exposure Auto** feature.

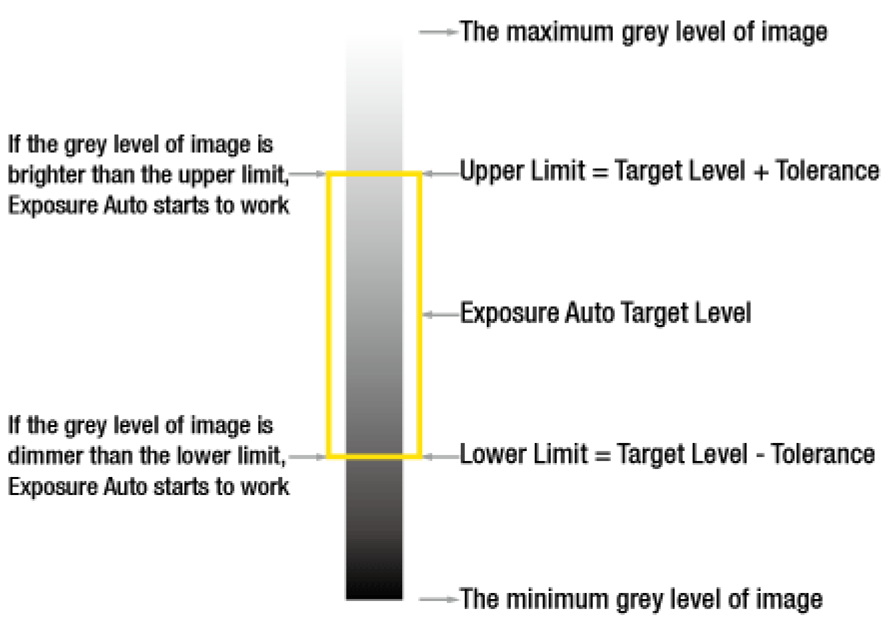


Figure 10.20 Exposure Auto Target Level and Exposure Auto Tolerance

Each auto feature has the following operating ranges depending on the object brightness level. You can set the operating range by adjusting the minimum and maximum value for each feature.

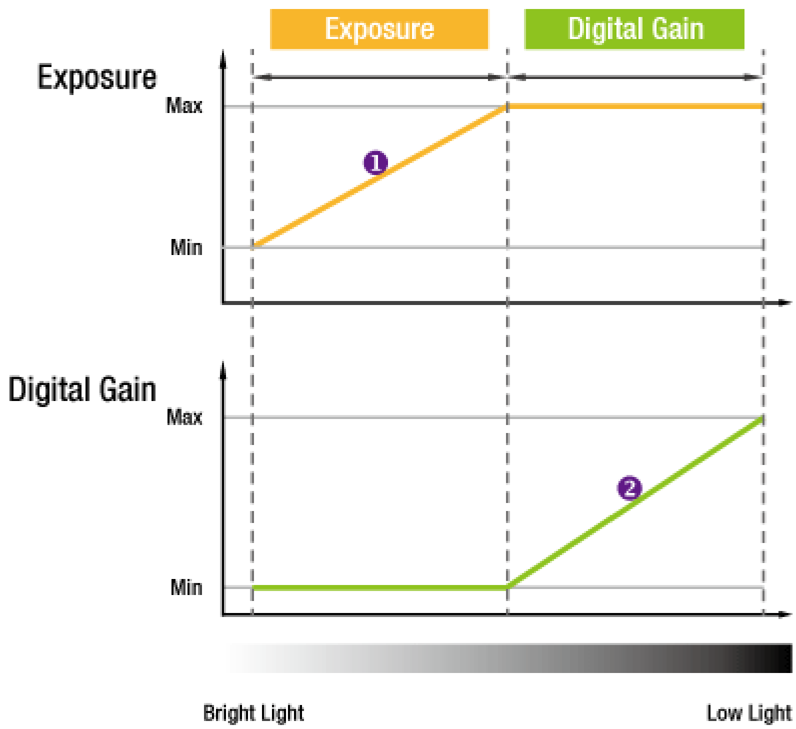


Figure 10.21 Image Level Adjustment

When the **Exposure Auto** or **Gain Auto** parameter is set to **Off**, the operating procedures are as follows.

Auto Features		Operating Procedures	Remarks
Exposure	**Gain**		
On	On	Exposure → Gain	Both the Exposure and Gain are adjusted automatically
On	Off	Exposure	Manually adjustable the Gain
Off	On	Gain	Manually adjustable the Exposure
Off	Off	-	Manually adjustable both the Exposure and Gain

Table 10.13 Operating Procedures for Auto Features

XML parameters related to AEC (Auto Exposure Control) are as follows.

XML Parameters		Value	Description
AcquisitionControl	ExposureAuto	Off	Exposure Auto Off
		Once	Target Level is adapted once and then Off
		Continuous	Target Level is constantly adapted
	ExposureAutoMin	Refer to Table 9.1	Lower limits of Exposure duration (The lower the value, the more smear)
	ExposureAutoMax	~7,000,000 µs	Upper limits of Exposure duration (The higher the value, the more motion blur)
	ExposureAutoTargetLevel	100~3995	Target average grey value (12bit†)
	ExposureAutoTolerance	100~2047	Tolerance of the target average grey value - 12 bit (If the current grey level is out of the tolerance, AEC starts to work.)
AnalogControl	GainAuto	Off	Gain Auto Off
		Once	Gain is adjusted once and then Off
		Continuous	Gain is constantly adjusted
	GainAutoMin	×1~×64	Lower limits of Gain
	GainAutoMax		Upper limits of Gain

Table 10.14 XML Parameters related to AEC

- You can set the **Exposure Auto** and **Gain Auto** feature in any order. However, we strongly recommend setting the one feature first while turning off the other features for the smooth operation.
- †: The maximum allowed **Exposure Auto Target Level** value may vary depending on the **Exposure Auto Tolerance** setting value.
  Exposure Auto Target Level = (0+Tolerance) ~ (4,095 –Tolerance)

10.9 Balance White Auto (Color Cameras)

The **Balance White Auto** feature is implemented on color cameras. It will control the white balance of the image acquired from the color camera according to the GeryWorld algorithm. Before using the **Balance White Auto** feature, you need to set the Data ROI for Balance White Auto. If you do not set the related Data ROI, the pixel data from the Image ROI will be used to control the white balance. As soon as the **Balance White Auto** parameter is set to **Once**, the Digital Red, Digital Green and Digital Blue will be set to 1. Then, Digital Red and Digital Blue will be adjusted to control the white balance.

XML parameters related to the Balance White Auto and RGB Gain settings are as follows.

<table>
<tr><th colspan="2">XML Parameters</th><th>Value</th><th>Description</th></tr>
<tr><td rowspan="8">AnalogControl</td><td rowspan="5">GainSelector</td><td>AnalogAll</td><td>Apply gain to all analog taps</td></tr>
<tr><td>DigitalAll</td><td>Apply gain to all digital channels</td></tr>
<tr><td>DigitalRed</td><td>Apply gain to red digital channel</td></tr>
<tr><td>DigitalGreen</td><td>Apply gain to green digital channel</td></tr>
<tr><td>DigitalBlue</td><td>Apply gain to blue digital channel</td></tr>
<tr><td>Gain</td><td>×0.5 ~ ×2.0</td><td>Set an absolute physical gain value when Digital Red, Green or Blue is selected</td></tr>
<tr><td rowspan="2">BalanceWhiteAuto</td><td>Off</td><td>Balance White Auto Off</td></tr>
<tr><td>Once</td><td>White Balance is adjusted once and then Off</td></tr>
</table>

Table 10.15 XML Parameters related to Balance White Auto

10.10 Gain and Black Level

You can set the analog (VGA) and digital gain factor to adjust the gain. The black level is adjusted by removing the optical black offset from the CCD so that the effect of dark current will be minimized.

10.10.1 Analog Domain

The VQ camera has one Analog Signal Processor (or Analog Front End (AFE)) for each channel. This AFE consists of Correlated Double Sampler (CDS), Variable Gain Amplifier (VGA), Black Level Clamp and 14-bit A/D converter.

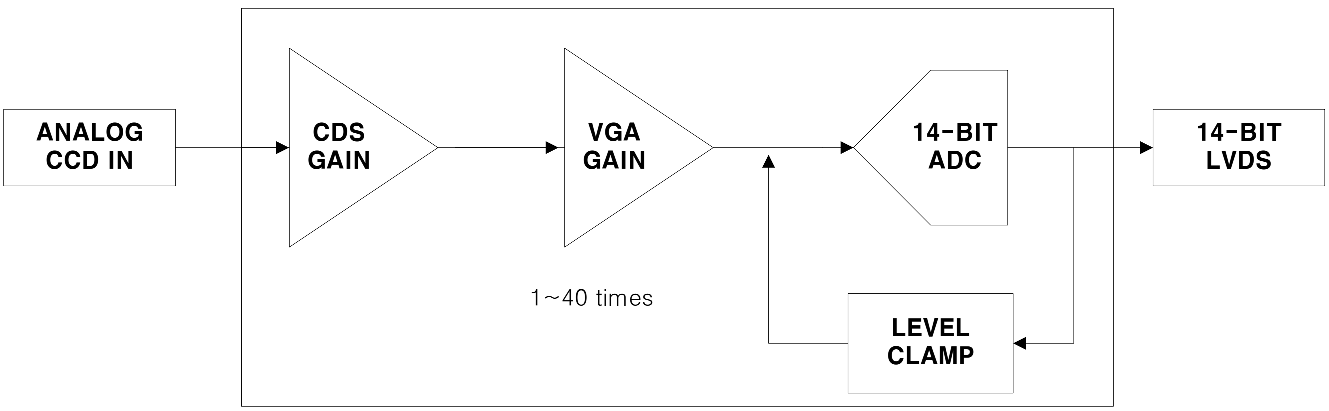


Figure 10.22 AFE Block Diagram

You can change the gain and black level value by inputting proper value into the registers for gain and black level adjustments inside the AFE. The CDS gain value is set in the factory during the manufacturing process, therefore you cannot change the value. The VGA gain is the same as the analog gain.
On VQ-5MG-16 model, you can set the analog gain for all analog taps or each tap. You can determine whether to control the gain balance between each tap manually or automatically by setting the **Gain Auto Balance** parameter to **Off** or **Once**. To balance the black level between each tap, use the **Black Level** parameter.

In VQ-310G-M400, you can change the gain and black level value by inputting proper value into the registers for gain and black level adjustments inside CMOS sensor.

10.10.2 Digital Domain

Digital gain is adjustable from 1 to ×64 with almost 1/1024 step. If the **Gain Auto** parameter is set to **Once** or **Continuous**, the digital gain value will be automatically adjusted according to the **Exposure Auto Target Level** parameter settings. XML parameters related to Gain and Black Level are as follows.

<table>
<tr><th colspan="2">XML Parameters</th><th>Value</th><th>Description</th></tr>
<tr><td rowspan="15">AnalogControl</td><td rowspan="5">GainSelector</td><td>AnalogAll</td><td>Apply gain to all analog taps</td></tr>
<tr><td>DigitalAll</td><td>Apply gain to all digital channels</td></tr>
<tr><td>DigitalRed</td><td>Apply gain to red digital channel</td></tr>
<tr><td>DigitalGreen</td><td>Apply gain to green digital channel</td></tr>
<tr><td>DigitalBlue</td><td>Apply gain to blue digital channel</td></tr>
<tr><td>Gain</td><td>-</td><td>Set an absolute physical gain value
• Analog All: ×1.0~×40 (Except VQ-310G-M400)
• Analog All: ×1.0~×3.5 (VQ-310G-M400)
• Digital All: ×1.0~×64</td></tr>
<tr><td rowspan="3">GainAuto</td><td>Off</td><td>Gain Auto Off</td></tr>
<tr><td>Once</td><td>Gain value is adjusted once and then Off</td></tr>
<tr><td>Continuous</td><td>Gain value is constantly adjusted</td></tr>
<tr><td>BlackLevelSelector</td><td>All</td><td>Apply black level to all taps</td></tr>
<tr><td>BlackLevel</td><td>0~255</td><td>• Set an absolute physical black level value.
(0 ~ 127 LSB @ 12bit, Except VQ-310G-M400)
• Set an absolute physical black level value.
(0 ~ 256 LSB @ 12bit, VQ-310G-M400)</td></tr>
</table>

Table 10.16 XML Parameters related to Gain and Black Level

10.11 LUT (Except VQ-5MG-16)

Lookup Table (LUT) converts original image values to certain level values.

Luminance

Since it is mapped one to one for each level value, 12-bit output can be connected to 12-bit input. LUT is in the form of table that has 4096 entries between 0~4095 and VQ camera provides a non-volatile space for LUT data storage. You can determine whether to apply LUT. For more information about how to download LUT to the camera, refer to Appendix B.

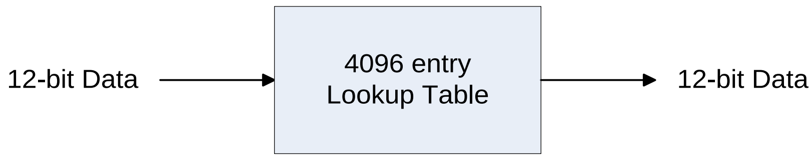


Figure 10.23 LUT Block

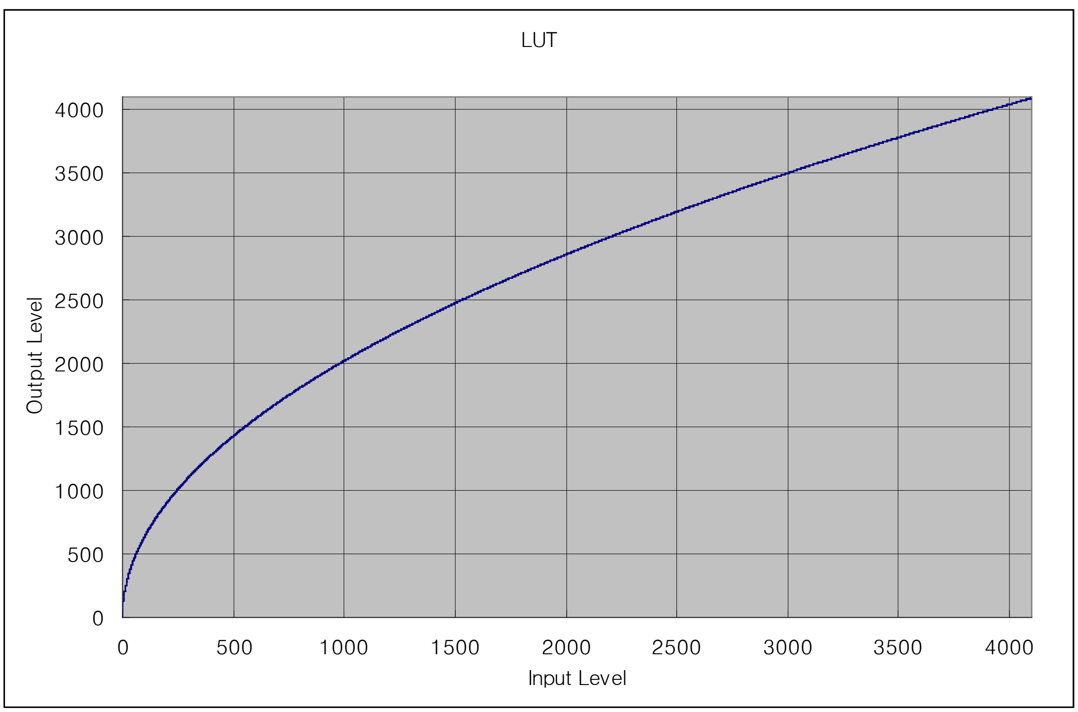


Figure 10.24 LUT at Gamma 0.5

XML parameters related to LUT are as follows.

XML Parameters		Value	Description
LUTControl	LUTSelector	Luminance	Luminance LUT
	LUTEnable	On	Activate the selected LUT
		Off	Deactivate the selected LUT
	LUTIndex	-	Index of coefficient for verifying the LUT Value • Luminance: 0 ~ 4095
	LUTValue	-	Output value of the current LUT corresponding to the input value of LUT Index

Table 10.17 XML Parameters related to LUT

The LUT feature does not supported on the VQ-5MG-16 model.

10.12 Defective Pixel Correction

The CCD may have defective pixels which cannot properly react to the light. Correction is required since it may deteriorate the quality of output image. Defective pixel information of CCD used for each camera is entered into the camera during the manufacturing process in the factory. If you want to add defective pixel information, it is required to enter coordinate of new defective pixel into the camera.

10.12.1 Correction Method

Correction value for a defective pixel is calculated based on valid pixel value adjacent in the same line.

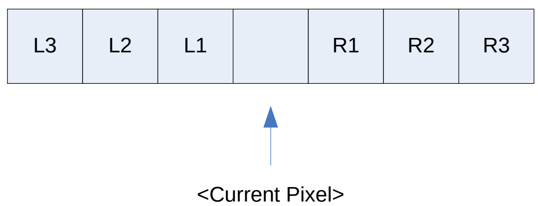


Figure 10.25 Location of Defective Pixel to Be Corrected

If current pixel is a defective pixel as shown in the above figure, correction value for this pixel is obtained as shown in the following table depending on whether surrounding pixel is defective pixel or not.

Adjacent Defective Pixel(s)	Correction Value of Current Pixel
None	(L1 + R1) / 2
L1	R1
R1	L1
L1, R1	(L2 + R2) / 2
L1, R1, R2	L2
L2, L1, R1	R2
L2, L1, R1, R2	(L3 + R3) / 2
L2, L1, R1, R2, R3	L3
L3, L2, L1, R1, R2	R3

Table 10.18 Calculation of Defective Pixel Correction Value

10.12.2 Correction Method in Binning Mode (Except VQ-310G-M400)

The **Defective Pixel Correction** feature is also available even when 2×2 or 4×4 binning is enabled. The correction value will be averaged based on four neighboring pixels during 2×2 binning and sixteen neighboring pixels during 4×4 binning.

XML parameter related to Defective Pixel Correction is as follows.

XML Parameters		Value	Description
ImageFormatControl	DefectivePixelCorrection	On	Apply a downloaded defective pixel map to the camera
		Off	Disable the application of the defective pixel map

Table 10.19 XML Parameter related to Defective Pixel Correction

ⓘ	To apply the **Defective Pixel Correction** feature, you must download a Defective Pixel Map to the camera. For more information about how to download a Defective Pixel Map to the camera, refer to Appendix A.

10.13 Temperature Monitor

A sensor chip is embedded in the camera to monitor the internal temperature.

XML parameter related to Device Temperature is as follows.

XML Parameters		Description
DeviceControl	DeviceTemperature	Display device temperature in Celsius

Table 10.20 XML Parameter related to Device Temperature

10.14 Status LED

A green LED is installed on the back panel of the camera to inform the operation status of the camera. LED status and corresponding camera status are as follows:

- Continuous ON: The camera operates in Trigger Off mode.
- Repeat ON for 0.5 seconds, OFF for 0.5 seconds: The camera operates in Trigger mode.
- Repeat ON for 1 second, OFF for 1 second: The camera outputs Test Image.
- Repeat ON for 0.25 second, OFF for 0.25 second: The camera operates in Trigger mode and outputs Test Image.

VQ-310G-M400's LED status and corresponding camera status are as follows:

- LED Off: The camera is powered off. No power to the camera.
- Steady Red: The camera is not initialized.
- Slow Flashing Orange: The camera is checking IP address.
- Fast Flashing Orange: Ethernet cable is disconnected.
- Steady Orange: IP address is assigned; The camera is not connected to any applications.
- Steady Green: The camera is connected to an application.
- Slow Flashing Green: The camera is acquiring images with the Trigger Mode set to ON.
- Fast Flashing Green: The camera is acquiring images in the free run mode.

10.15 Test Image

To check whether the camera operates normally or not, it can be set to output test images generated in the camera, instead of the image data from the CCD. Three types of test images are available; image with different value in horizontal direction (Grey Horizontal Ramp), image with different value in diagonal direction (Grey Diagonal Ramp), and moving image with different value in diagonal direction (Grey Diagonal Ramp Moving). XML parameters related to Test Image are as follows.

<table>
<tr><th colspan="2">XML Parameters</th><th>Value</th><th>Description</th></tr>
<tr><td rowspan="4">ImageFormatControl</td><td rowspan="4">TestImageSelector</td><td>Off</td><td>Test Image Off</td></tr>
<tr><td>GreyHorizontalRamp</td><td>Set to Grey Horizontal Ramp</td></tr>
<tr><td>GreyDiagonalRamp</td><td>Set to Grey Diagonal Ramp</td></tr>
<tr><td>GreyDiagonalRampMoving</td><td>Set to Grey Diagonal Ramp Moving</td></tr>
</table>

Table 10.21 XML Parameter related to Test Image

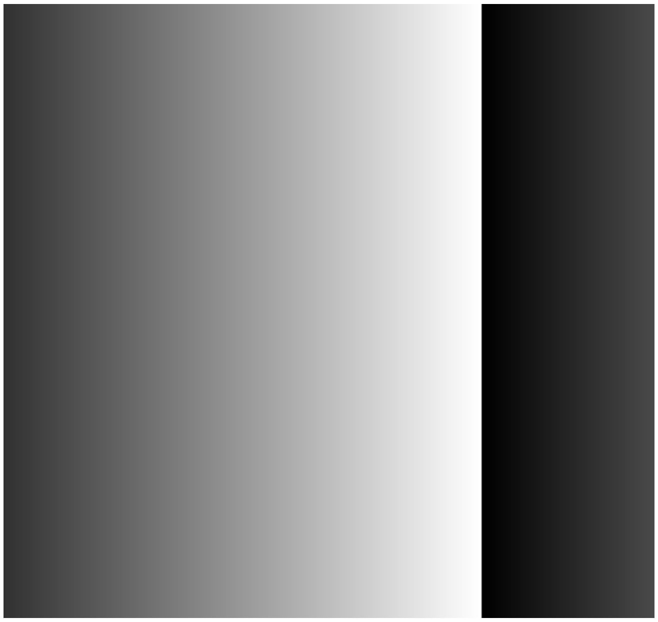


Figure 10.26 Grey Horizontal Ramp

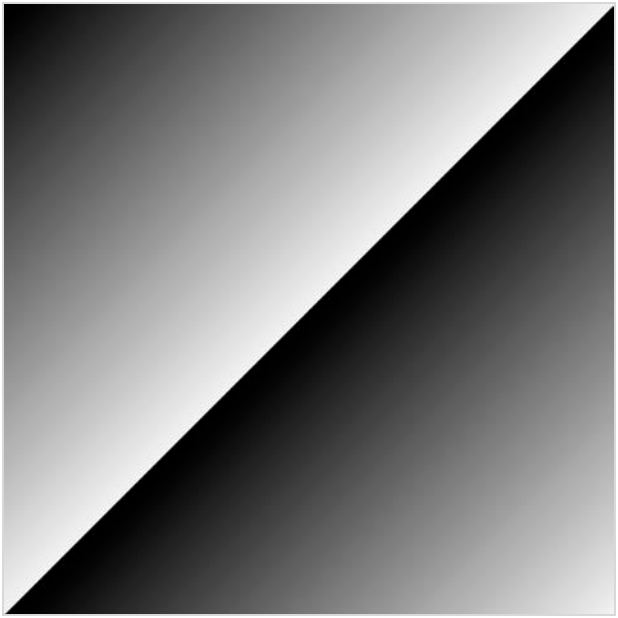


Figure 10.27 Grey Diagonal Ramp

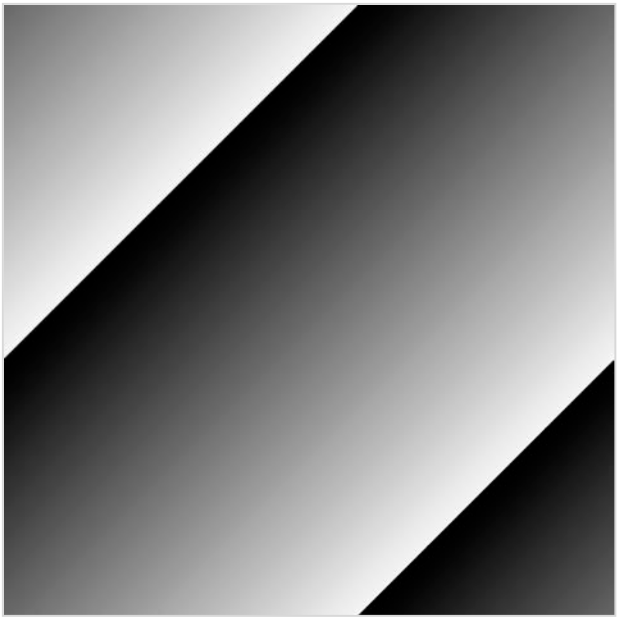


Figure 10.28 Grey Diagonal Ramp Moving

CAUTION	The test image may look different because the region of the test image may vary depending on the camera's resolution.

10.16 Digital IO Control

The pin number 4 of the Power Input and Control I/O Receptacle is designated as programmable output and can be operated in various modes.

XML parameters related to Digital IO Control are as follows.

XML Parameters		Value	Description
DigitalIO Control	LineInverter	On	Enable inversion on the output signal of the line
		Off	Disable inversion on the output signal of the line
	LineSource	Off	Disable the line output
		ExposureActive	Output pulse signals indicating the current exposure time
		FrameActive	Output pulse signals indicating a frame readout time
		StrobeOut	Output Exposure Active signals with Strobe Out Delay
		PulseGenerator	Output user defined pulse signals
		UserOutput	Output User Output signal set by User Output Value
	UserOutputValue	On	Set the bit state of the line to High
		Off	Set the bit state of the line to Low
	PulsePeriod	1~60,000,000	Set a pulse period in microseconds when the Line Source is set to Pulse Generator
	PulseWidth	0~60,000,000	Set a pulse width in microseconds when the Line Source is set to Pulse Generator
	StrobeOutDelay	0~65535	Set a delay in microseconds when the Line Source is set to Strobe Out

Table 10.22 Digital IO Control

The camera can provide an **Exposure Active** output signal. The signal goes high when the exposure time for each frame acquisition begins and goes low when the exposure time ends as shown in Figure 10.28. This signal can be used as a flash trigger and is also useful when you are operating a system where either the camera or the object being imaged is movable. Typically, you do not want the camera to move during exposure. You can monitor the **Exposure Active** signal to know when exposure is taking place and thus know when to avoid moving the camera.

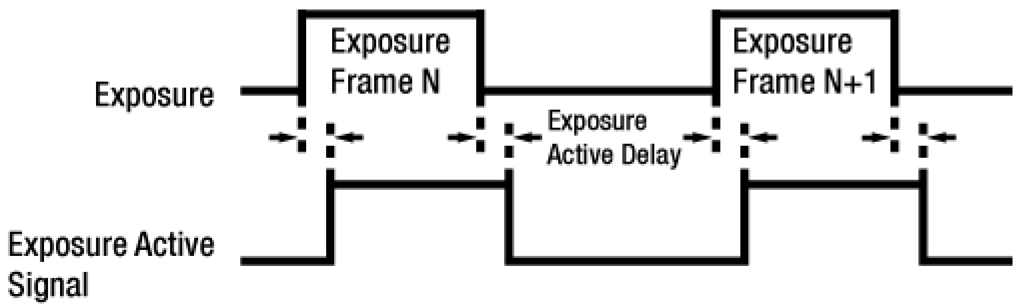


Figure 10.29 Exposure Active Signal

	When you use the Exposure Active signal, be aware that there is an Exposure Active Delay between the point where exposure actually begins and the point where the signal rises. See Figure 10.29 and Table 10.23.

Model	Exposure Active Delay
VQ series	68 ㎲
VQ-310G-M400	• Active High: 106 ㎲ • Active Low: 24 ㎲

Table 10.23 Exposure Active Delay

10.17 Event Control

VQ camera provides an Event Notification feature. With the Event Notification feature, the camera can generate an event and transmit a related event message to the PC whenever a specific situation has occurred.

The camera can generate and transmit events for the following type of situation:

- The end of an exposure has occurred (Exposure End)

XML parameters related to Event Control are as follows.

XML Parameters		Value	Description
EventControl	EventSelector	ExposureEnd	Select which particular event to control • Exposure End event is only available
	Event Notification	On	Enable the selected event notification
		Off	Disable the selected event notification
TransportLayer Control	GevTimestampControlLatch	-	Latch the current time stamp counter into GevTimestampValue.
	GevTimestampControlReset	-	Reset the time stamp counter to 0.

Table 10.24 XML Parameters related to Event Control

10.18 Device User ID

You can input user defined information up to 16 bytes.

XML parameter related to Device User ID is as follows.

XML Parameters		Description
DeviceControl	DeviceUserID	Input user defined information (16 bytes)

Table 10.25 XML Parameter related to Device User ID

10.19 Device Reset

Reset the camera physically to power off and on. You must connect to the network because the camera will be released from the network after reset. XML parameter related to Device Reset is as follows.

XML Parameters		Description
DeviceControl	DeviceReset	Reset the camera physically

Table 10.26 XML Parameter related to Device Reset

10.20 User Set Control

You can save the current camera settings to the camera's internal ROM. You can also load the camera settings from the camera's internal ROM. The camera provides two setups to save and three setups to load settings. XML parameters related to User Set Control are as follows.

XML Parameters		Value	Description
UserSetControl	UserSetSelector	Default	Select the Factory Default settings
		UserSet1	Select the User Set1 settings
		UserSet2	Select the User Set2 settings
	UserSetLoad	-	Load the User Set specified by User Set Selector to the camera
	UserSetSave	-	Save the current settings to the User Set specified by User Set Selector Default is allowed to load only.
	UserSetDefaultSelector	Default	Apply the Factory Default settings when reset
		UserSet1	Apply the User Set1 settings when reset
		UserSet2	Apply the User Set2 settings when reset

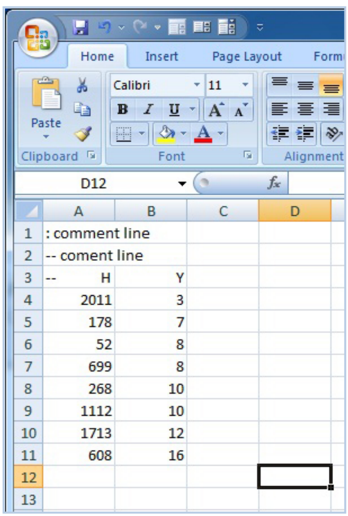
Table 10.27 XML Parameters related to User Set Control

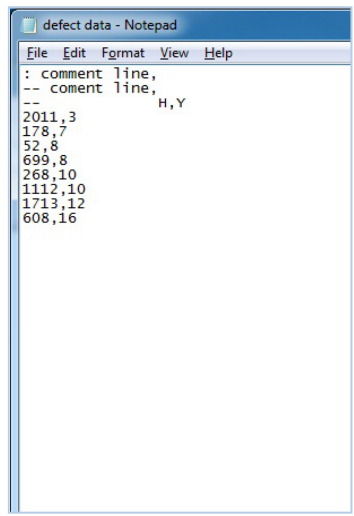
10.21 Field Upgrade

The camera provides a feature to upgrade Firmware and FGPA logic through Gigabit Ethernet interface rather than disassemble the camera in the field. Refer to Appendix C for more details on how to upgrade.

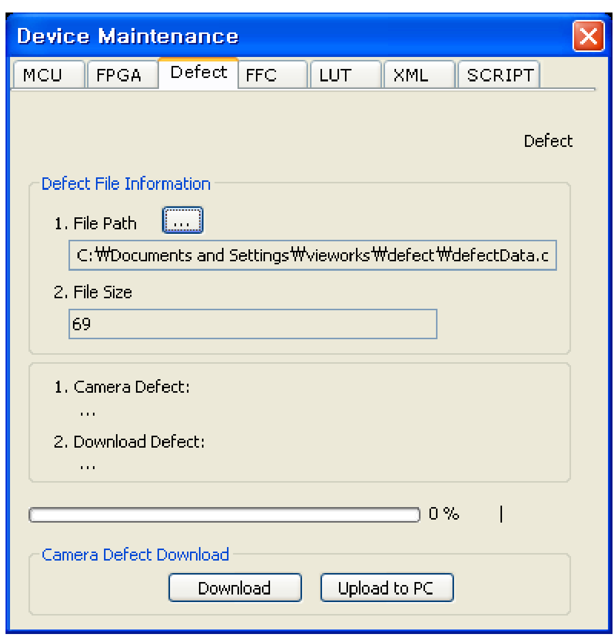
Appendix A Defective Pixel Map Download

1. Create the Defective Pixel Map data in Microsoft Excel format as shown in the left picture below and save as a CSV file (*.csv). The picture in the right shows the created Excel file opened in Notepad. The following rules need to be applied when creating the file.
    - Lines beginning with ':' or '—' are treated as notes.
    - Each row is produced in the order of the horizontal and vertical coordinate values.
    - The input sequence of pixel is irrelevant.

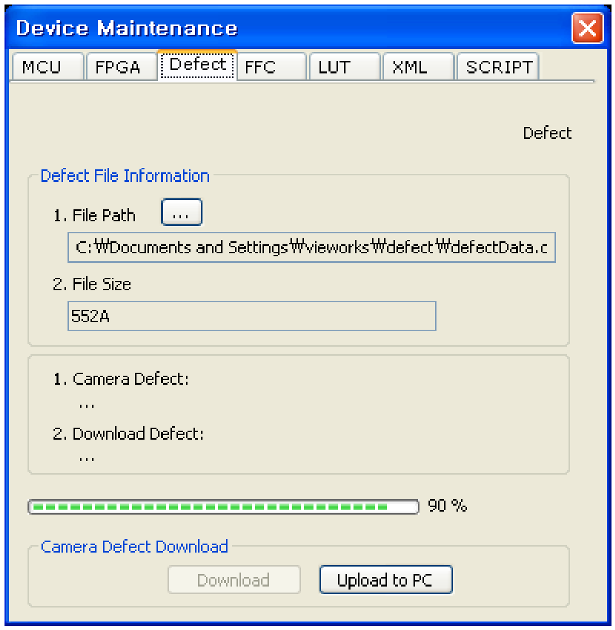




2. Run Vieworks Imaging Solution 6.X and click the **Configure** button to display the window as shown below. Select the **Defect** tab, click the **File Path** button, search and select the defective pixel map file (*.csv), and then click the **Download** button.



3. Once the download is complete, the saving process will begin. During the saving process, make sure not to disconnect the power cord.



4. After completing the download, click the **OK** button to close the confirmation.

Appendix B LUT Download (Except VQ-5MG-16)

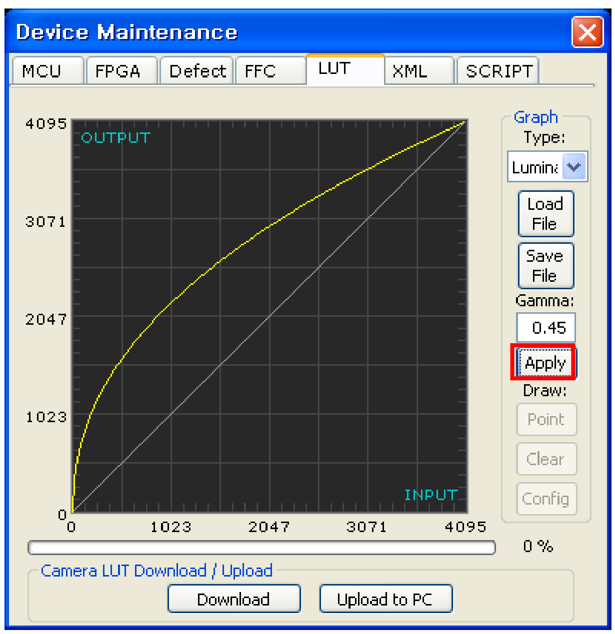
LUT data can be created in two ways; by adjusting the gamma values on the gamma graph provided in the program and then downloading the data or by opening a CSV file (*.csv) and then downloading the data.

B.1 Luminance LUT

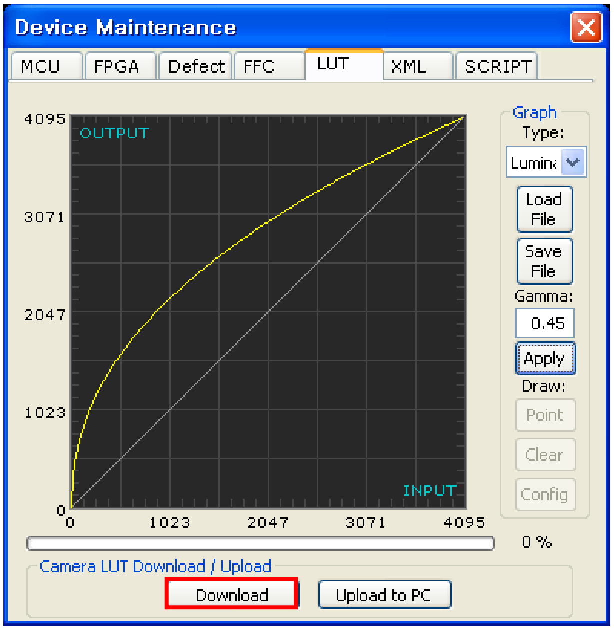
B.1.1 Gamma Graph Download

1. Run Vieworks Imaging Solution 6.X and click the **Configure** button to display the window as shown below. Select the **LUT** tab, and then select **Luminance** from the **Type** dropdown list.

2. Set a desired value in the **Gamma** input field and click the **Apply** button.



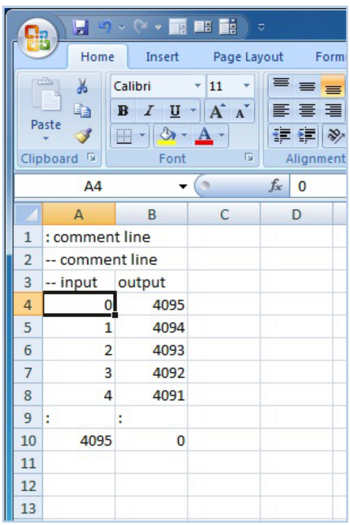
3. Click the **Download** button to download the gamma set to the camera.

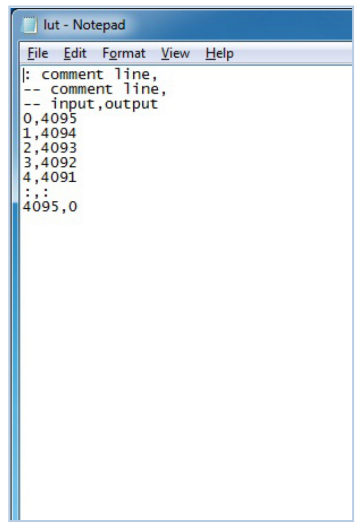


4. After completing the download, click the **OK** button to close the confirmation.

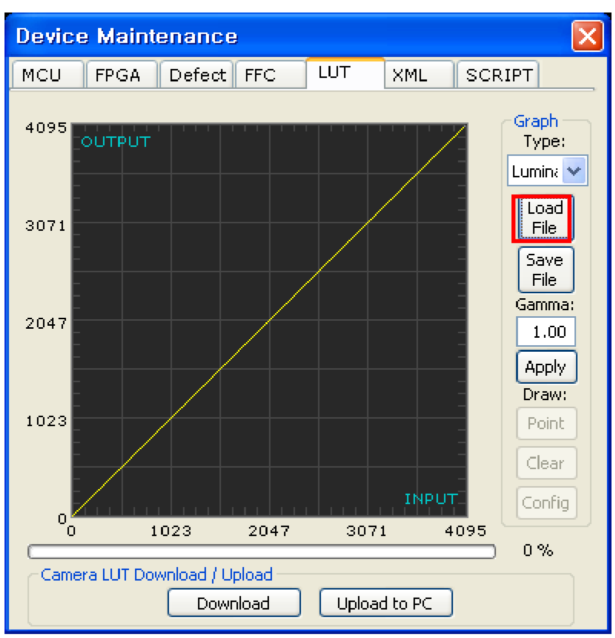
B.1.2 CSV File Download

1. Create the LUT table in Microsoft Excel format as shown in the left picture below and save as a CSV file (*.csv). The picture in the right shows the created file opened in Notepad. Once the file has been created completely, change the .csv file extension to .lut. The following rules need to be applied when creating the file.
   - Lines beginning with ':' or '—' are treated as notes.
   - Based on the input values, make sure to record from 0 to 4095.

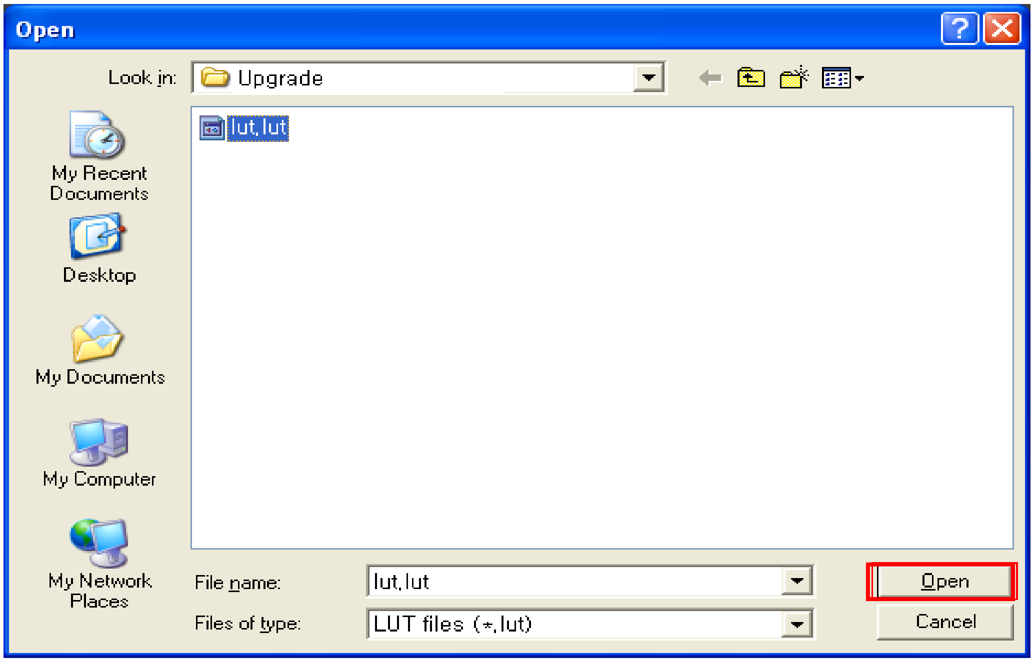




2. Run Vieworks Imaging Solution 6.X and click the **Configure** button to display the window as shown below. Select the **LUT** tab, select **Luminance** from the **Type** dropdown list, and then click the **Load File** button.



3. Search and select the created LUT file and click the **Open** button.

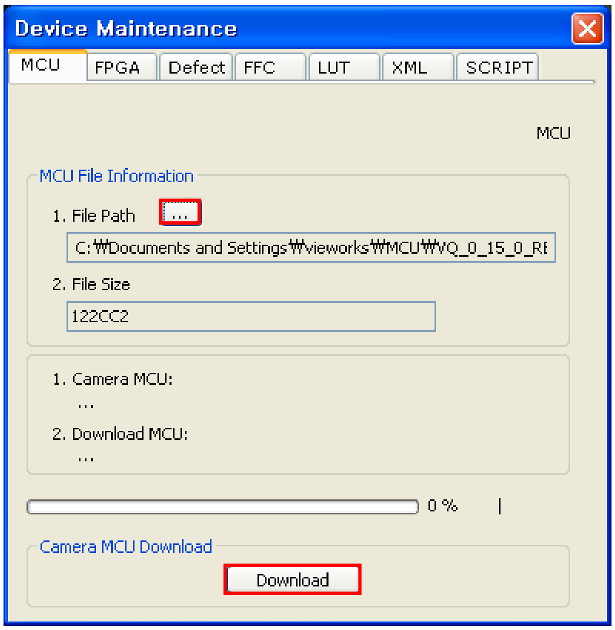


4. Click the **Download** button. After completing the download, click the **OK** button to close the confirmation.

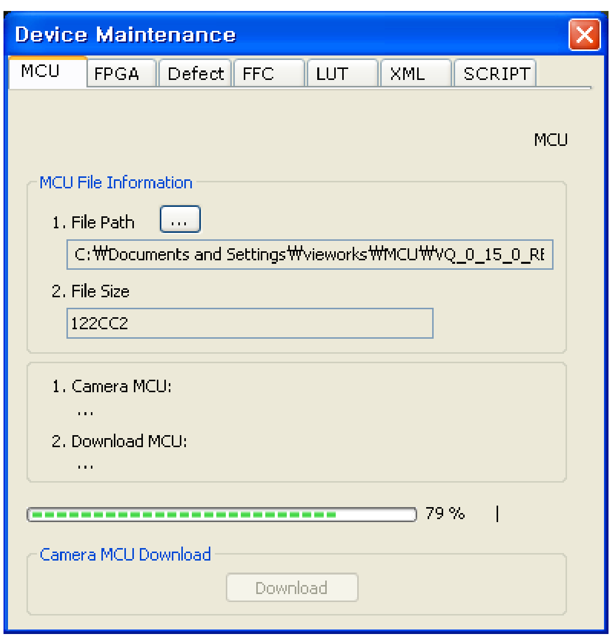
Appendix C Field Upgrade

C.1 MCU

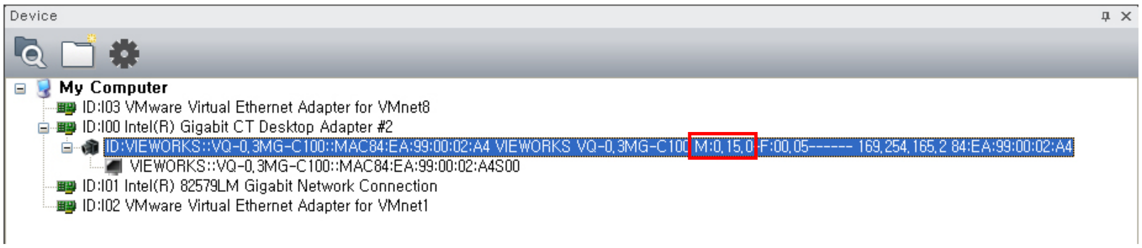
1. Run Vieworks Imaging Solution 6.X and click the **Configure** button to display the window as shown below.
2. Select the **MCU** tab, click the **File Path** button, search and select the MCU upgrade file (*.srec, upgrade file for VQ-310G-M400 is *.mcu), and then click the **Download** button.



3. MCU upgrade file download starts and the downloading status is displayed at the bottom of the window.

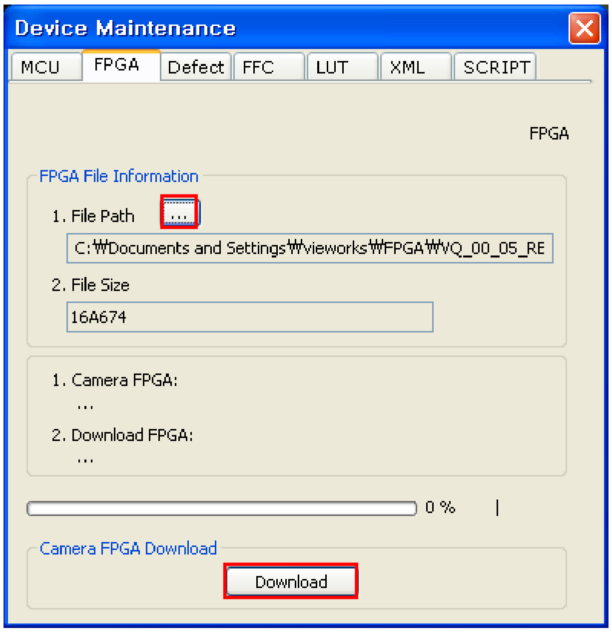


4. Once all the processes have been completed, turn the power off and turn it back on again. Check the DeviceVersion parameter value to confirm the version. Or, check under the My Computer to verify the upgraded version.



C.2 FPGA

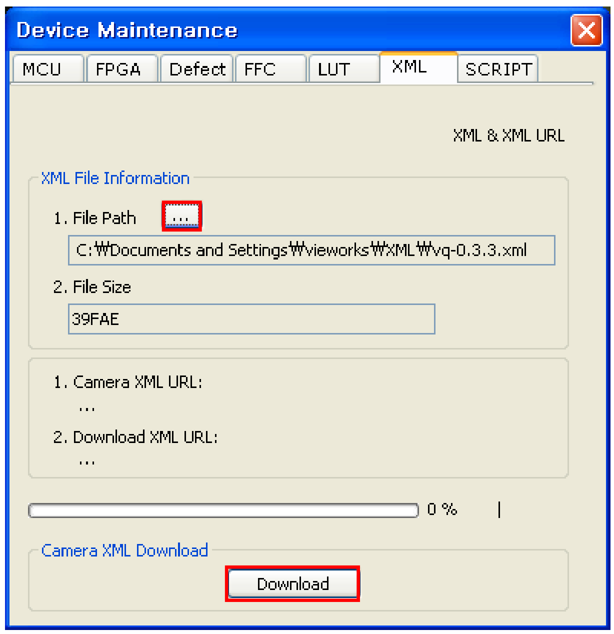
1. Run Vieworks Imaging Solution 6.X and click the **Configure** button to display the window as shown below.
2. Select the **FPGA** tab, click the **File Path** button, search and select the FPGA upgrade file (*.bin), and then click the **Download** button.



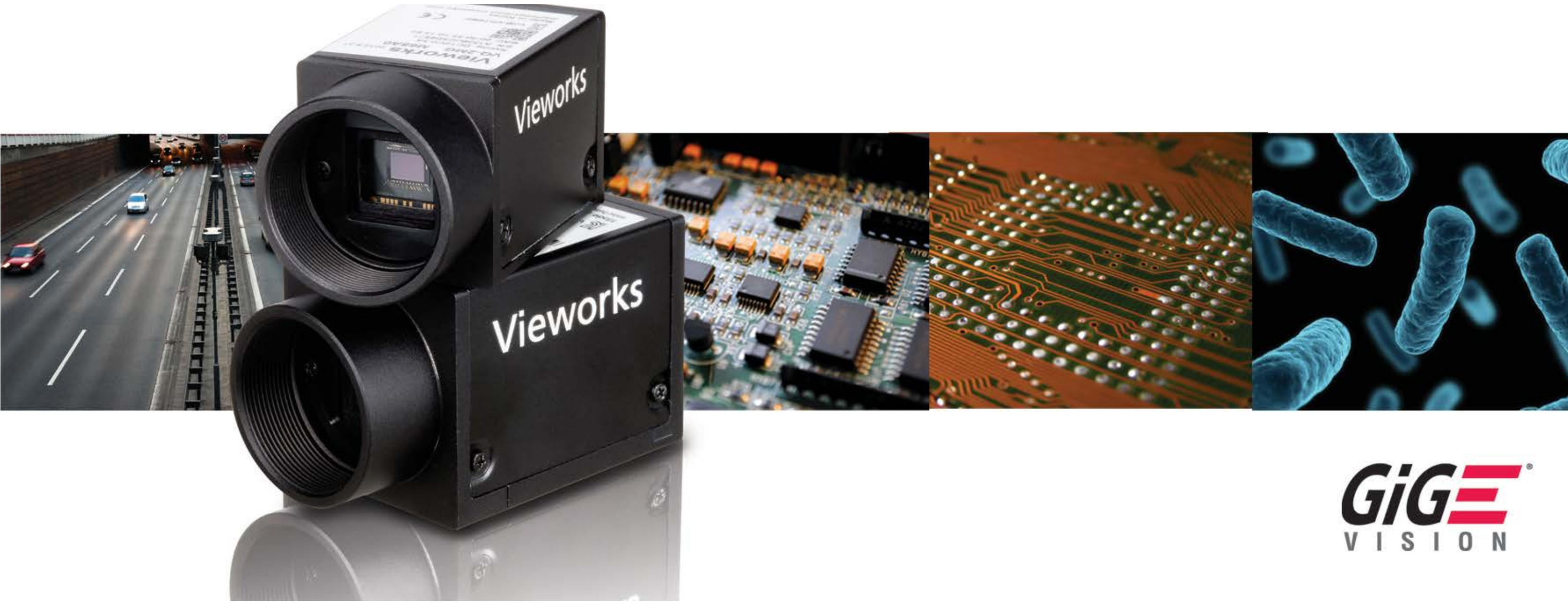
3. The subsequent processes are identical to those of MCU upgrade.

C.3 XML

1. Run Vieworks Imaging Solution 6.X and click the **Configure** button to display the window as shown below.
2. Select the **XML** tab, click the **File Path** button, search and select the XML upgrade file (*.zip), and then click the **Download** button.



3. The subsequent processes are identical to those of MCU upgrade.



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