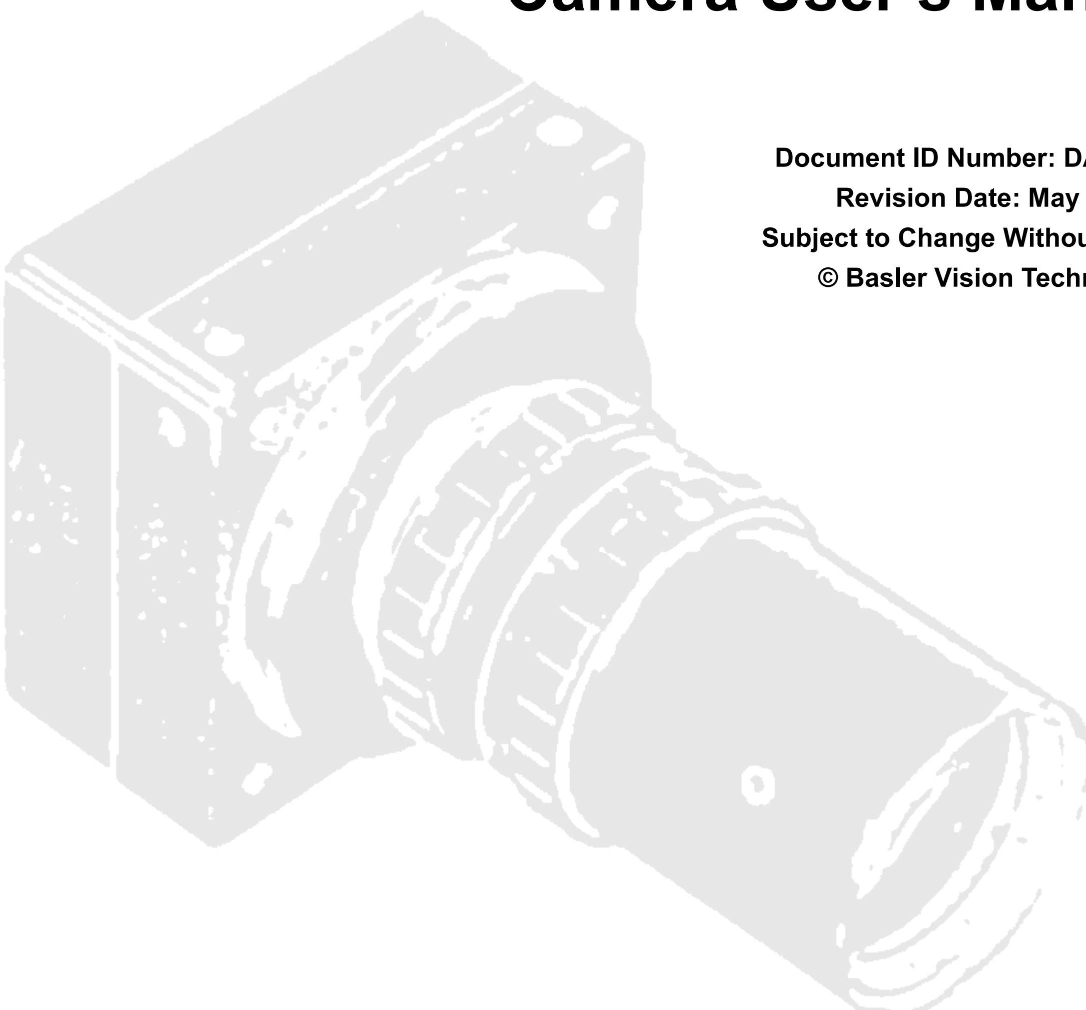
BASLER A101f
Camera User's Manual



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For customers in the U.S.A.

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

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

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

For customers in Canada

This apparatus complies with the Class A limits for radio noise emissions set out in Radio Interference Regulations.

Pour utilisateurs au Canada

Cet appareil est conforme aux normes Classe A pour bruits radioélectriques, spécifiées dans le Règlement sur le brouillage radioélectrique.

Life Support Applications

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Basler customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Basler for any damages resulting from such improper use or sale.

Warranty Note

Do not open the housing of the camera. The warranty becomes void if the housing is opened.

Table of Contents

1 Introduction

The **BASLER A101f** progressive scan camera is a versatile camera designed for industrial use. Superb image sensing features are combined with a robust, high precision housing.

Important features are:

- Compliant with the 1394 TA Digital Camera Specification (V 1.20)
- High spatial resolution
- High sensitivity
- Anti-blooming
- Asynchronous full frame shutter via electronic control
- Square sensor cells
- High Signal-to-Noise Ratio
- Area of interest (AOI) scanning
- Binning mode
- Correlated double-sampling
- Industrial housing manufactured with high planar, parallel and angular precision
- Compact size

1.1 Camera Models

The camera is available in a monochrome model (the **A101f**) and a color model (the**A101fc**). Throughout the manual, the camera will be called the **A101f**. Passages that are only valid for a specific model will be so indicated.

1.2 Performance Specifications

Specification	A101f
Sensor Type	Sony ICX085AL/AK - 2/3 inch, HAD, interline transfer, progressive scan CCD
Pixels	1300 (H) x 1030 (V)
Pixel Size	6.7 µm (H) x 6.7 µm (V)
Anti-Blooming	1:100
Dark Signal Non-uniformity	± 1 DN
Photo Response Non-uniformity	± 5%
Max. Frame Rate (at full resolution)	12 frames/sec.
Video Output Signal	Mono: 8 bits per pixel, IEEE 1394 Compliant Color: YUV 4:2:2, 16 bits/pixel average, IEEE 1394 Compliant
Gain and Brightness	Programmable via IEEE 1394 bus
Exposure Time Control	Programmable via IEEE 1394 bus
Synchronization	External via External Trigger signal ExTrig input is opto-isolated, max. 1.4 V, max 50 mA
Power Requirements	12 VDC (± 10%), 5.0 W, < 1% ripple supplied via 1394 cable
Max. Cable Lengths	1394: 4.5 m I/O: 10 m
Shock	20G with 50 repetitions in each axis
Vibration	10G (58-500Hz) for 1 hour in each axis
Lens Adapter	C-mount or F-mount
Housing Size (L x W x H)	without lens adapter: 48.7 mm x 62 mm x 62 mm with C-mount adapter: 51.2 mm x 62 mm x 62 mm with F-mount adapter: 80.2 mm x 62 mm x 62 mm
Weight	without lens adapter: ~ 202 g with C-mount adapter: ~ 242 g with F-mount adapter: ~ 310 g
Conformity	CE, FCC

Table 1-1: Performance Specifications

The spectral responsivity for monochrome cameras is shown in Figure 1-1. The graph includes lens characteristics and excludes light source characteristics.

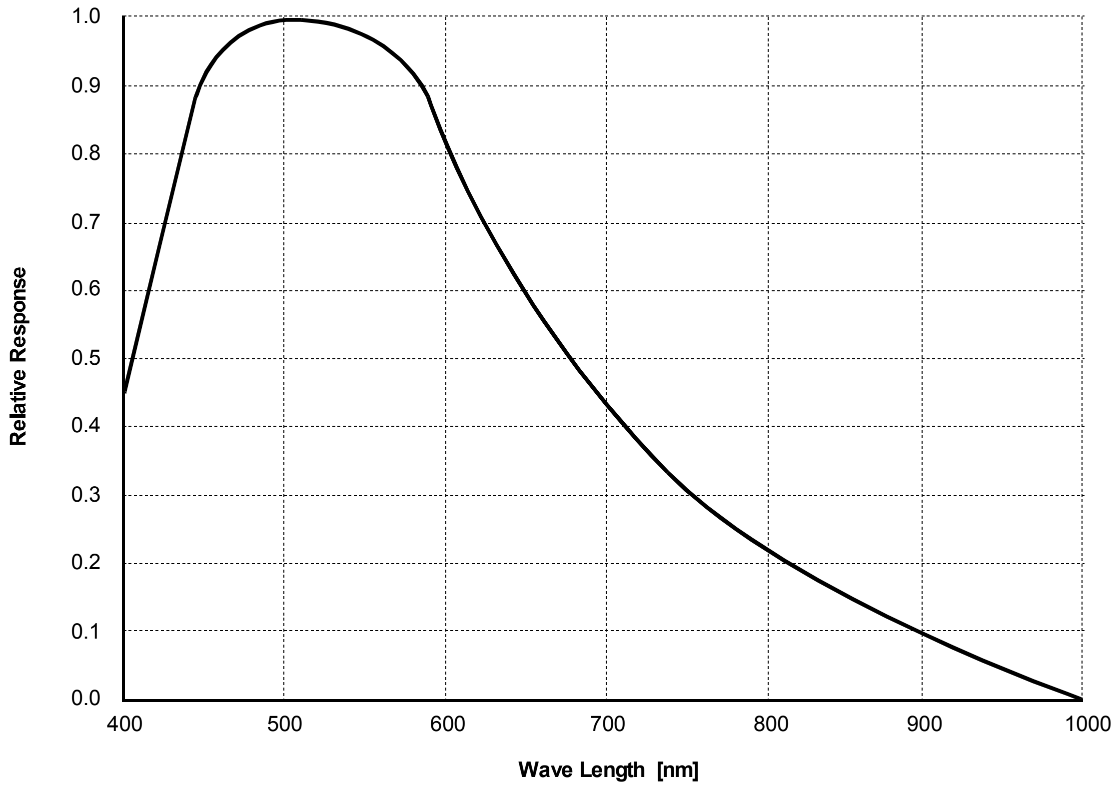


Figure 1-1: Spectral Responsivity - Monochrome Cameras

The spectral responsivity for color cameras is shown in Figure 1-2. The graph includes lens characteristics and excludes light source characteristics.

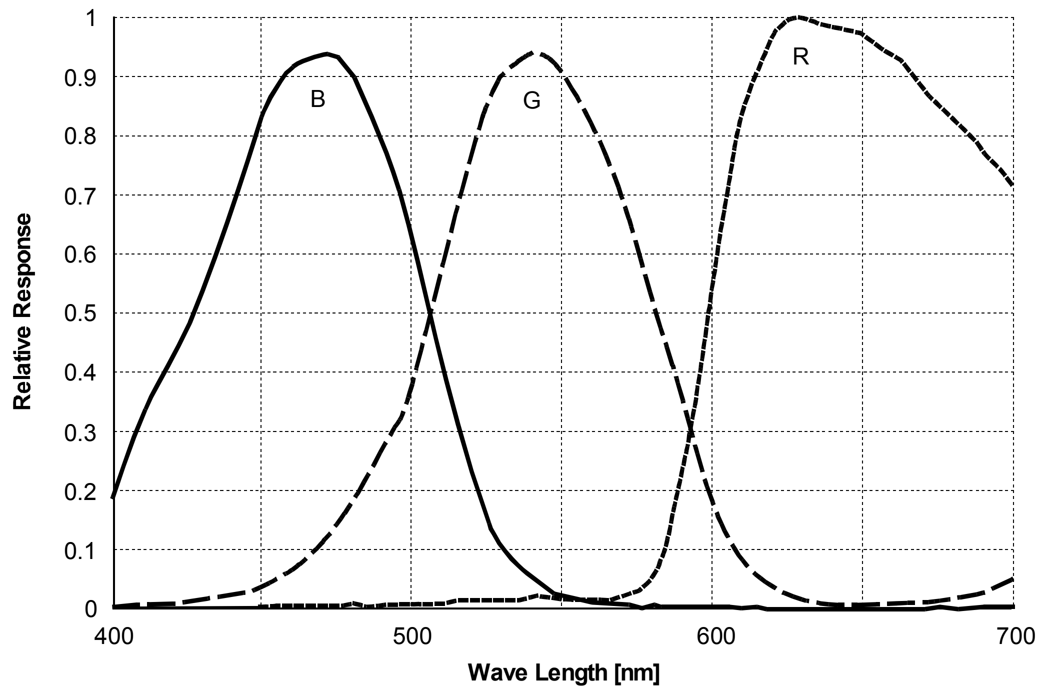


Figure 1-2: Spectral Responsivity - Color Cameras

☝	Cameras equipped with a C-mount lens adapter contain an integrated IR cut filter. On cameras equipped with an F-mount adapter, use of a suitable IR cut filter is recommended to maintain spectral balance and optimum MTF.

1.3 Environmental Requirements

1.3.1 Temperature and Humidity

Housing temperature during operation:	0° C … + 50° C (+ 32° F … +122° F)
Humidity during operation:	20% … 80%, relative, non-condensing

1.3.2 Ventilation

Allow sufficient air circulation around the camera to prevent internal heat build-up in your system and to keep the camera housing temperature below 50° C. Provide additional cooling such as fans or heat sinks if necessary.

Warning!

Without sufficient cooling, the camera can get hot enough during operation to cause burning when touched.

1.4 Precautions

Read the manual

Read the manual carefully before using the camera.

Keep foreign matter outside of the camera

Do not open the casing. Touching internal components may damage them.

Be careful not to allow liquid, flammable, or metallic material inside the camera housing. If operated with any foreign matter inside, the camera may fail or cause a fire.

Electromagnetic Fields

Do not operate the camera in the vicinity of strong electromagnetic fields. Avoid electrostatic charging.

Transporting

Only transport the camera in its original packaging. Do not discard the packaging.

Cleaning

Avoid cleaning the surface of the CCD sensor if possible. If you must clean it, use a soft, lint free cloth dampened with a small quantity of pure alcohol. Do not use methylated alcohol.
Because electrostatic discharge can damage the CCD sensor, you must use a cloth that will not generate static during cleaning (cotton is a good choice).

To clean the surface of the camera housing, use a soft, dry cloth. To remove severe stains, use a soft cloth dampened with a small quantity of neutral detergent, then wipe dry.

Do not use volatile solvents such as benzine and thinners; they can damage the surface finish.

2 Camera Interface

2.1 Connections

2.1.1 General Description

The A101f is interfaced to external circuitry via an IEEE 1394 socket and a 9-pin micro-D plug located on the side of the housing. Figure 2-1 shows the location of the two connectors. There are also two status LEDs on the back of the camera. The LEDs indicate signal integrity and power OK (see Section 6.1).

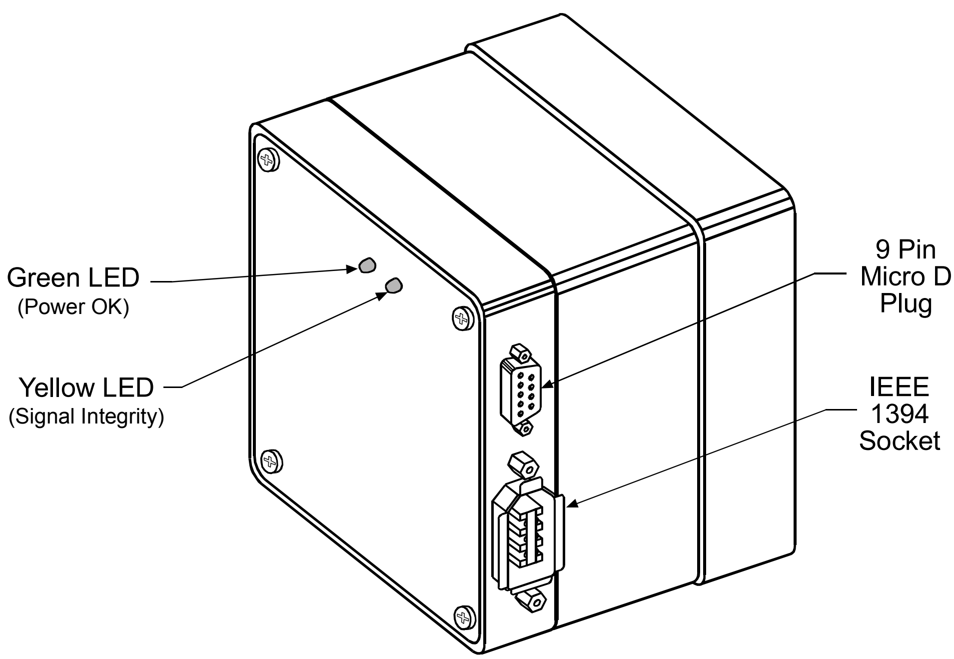


Figure 2-1: Camera Connectors and Indicators

2.1.2 Pin Assignments

The IEEE 1394 socket is used to supply power to the camera and to interface video data and control signals. The pin assignments for the socket are shown in Table 2-1.

Pin	Signal	Pin	Signal
1	+12 VDC	4	TPB+
2	DC Gnd	5	TPA-
3	TPB-	6	TPA+

Table 2-1: Pin Assignments for the IEEE 1394 Socket

The 9-pin micro-D plug is used to interface the external trigger, integrate enabled, and trigger ready signals. The pin assignments for the plug are shown in Table 2-2

Pin	Signal	Pin	Signal
1	External Trigger +	6	External Trigger -
2	Integrate Enabled +	7	Integrate Enabled -
3	Trigger Ready +	8	Trigger Ready -
4	Not Connected	9	Not Connected
5	Not Connected		

Table 2-2: Pin Assignments for the 9-Pin Micro-D Plug

The camera housing is not grounded and is isolated from the circuit boards inside of the camera.

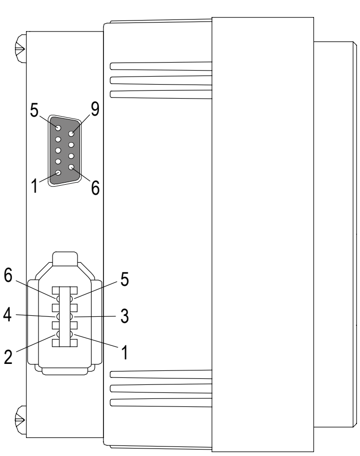


Figure 2-2: A101f Pin Numbering

2.1.3 Connector Types

The 6-pin connector on the camera is a standard IEEE-1394 socket.

The 9-pin Micro-D plug is Molex Part Number 83611-9006 or the equivalent.

2.2 Video Data and Control Signals

2.2.1 Input Signals

2.2.1.1 ExTrig: Controls Exposure Start

An external trigger (ExTrig) signal can be used to control the start of exposure. ExTrig can be a periodic or a non-periodic function. When the camera is operating under the control of an ExTrig signal, the frequency of the ExTrig signal determines the camera's frame rate. For more detailed information on using the ExTrig signal, see Sections 3.2 and 3.3.

As shown in Figure 2-3, the input for the ExSync signal is opto-isolated. The voltage of the LED in the opto-coupler is 1.4 V. The absolute maximum input current for the LED is 50 mA.[1]

For the ExSync input, a current of more than 5 mA means a logical one. A current of less than 0.1 mA means a logical zero.

2.2.2 Output Signals

2.2.2.1 IntEn: Indicates that Exposure is Taking Place

The integration enabled (IntEn) signal indicates that exposure is taking place. The IntEn signal will be high during exposure and low when exposure is not taking place.

As shown in Figure 2-3. the output for the IntEn signal is opto-isolated. The maximum forward voltage is 35 V, the maximum reverse voltage is 6 V, and the maximum collector current is 100 mA.[1]

A conducting transistor means a logical one and a non-conducting transistor means a logical zero.

2.2.2.2 TrigRdy: Indicates that Exposure Can Begin

When the trigger ready (TrigRdy) signal goes high, it indicates that exposure of the next frame can be triggered. Section 3.3 explains the operation of the trigger ready signal in more detail.

As shown in Figure 2-3. the output for the TrigRdy signal is opto-isolated. The maximum forward voltage is 35 V, the maximum reverse voltage is 6 V, and the maximum collector current is 100 mA.[1]

A conducting transistor means a logical one and a non-conducting transistor means a logical zero.

[1] The opto-isolator used in the camera is a Sharp PC3Q64Q or the equivalent. A detailed spec sheet for this device is available at the Sharp Microelectronics Group (www.sharpmeg.com).

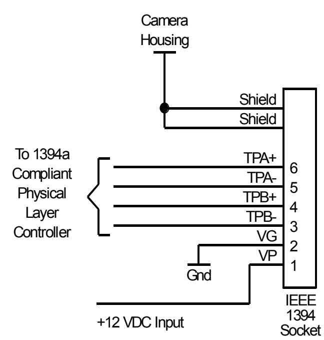
2.2.2.3 Pixel Data

Pixel data are transmitted as isochronous data packets according to version 1.20 of the “1394 - based Digital Camera Specification” issued by the 1394 Trade Association. The first packet of each frame is identified by a 1 in the sync bit of the packet header.

The video data for each pixel is output in an 8 bit format. Thus the range of intensity for each pixel includes 256 gray levels. The digital gray value of 0 corresponds to black and the digital gray value of 255 to white.

2.2.3 IEEE 1394 Device Information

The **A101f** uses an IEEE 1394a compliant physical layer device to transmit pixel data. Detailed spec sheets for devices of this type are available at the Texas Instruments web site (www.ti.com).



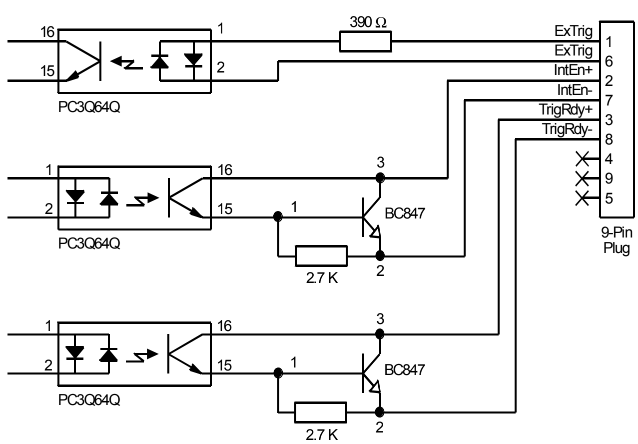


Figure 2-3: I/O Schematic

2.3 Camera Power

Power must be supplied to the camera via the IEEE 1394 cable. The camera requires +12 VDC ± 10%. Maximum power consumption is 5.0 W for the **A101f**. Ripple must be less than 1%.

2.4 Status LEDs

Green LED

The green LED on the back of the camera is used to indicate whether power is being supplied to the camera. When the green LED is out, it means that no power is present. When the green LED is lit, it means that power is present.

> Keep in mind that the circuit used to light the green LED does not perform a range check. If power to the camera is present but it is out of range, the LED may be lit but the camera will not operate properly.

Yellow LED

The yellow LED indicates signal integrity. In case of an error, blinking signals from the yellow LED indicate that an error condition is present. See Section 6.1 for more information.

3 Operation and Features

3.1 Functional Description

The **A101f** area scan camera employs a CCD-sensor chip which provides features such as electronic exposure time control and anti-blooming.

Normally, exposure time and charge readout are controlled by values transmitted to the camera's control registers via the IEEE 1394 interface. Command registers are available to set exposure time and frame rate. There are also command registers available to set the camera for single frame capture, multiple frame capture, and continuous frame capture.

Exposure start can also be controlled via an externally generated trigger (ExTrig) signal. The ExTrig signal facilitates periodic or non-periodic start of exposure. When exposure start is controlled by an ExTrig signal, exposure begins when the trigger signal goes low and continues for a pre-programmed period of time. Accumulated charges are read out when the programmed exposure time ends.

At readout, accumulated charges are transported from the sensor's light-sensitive elements (pixels) to the vertical shift registers (see Figure 3-1). The charges from the bottom line of pixels in the array are then moved into a horizontal shift register. As charges move out of the horizontal shift register, they are converted to voltages which are proportional to the size of each charge. Shifting is clocked according to the camera's internal data rate.

The voltages moving out of the horizontal shift register are amplified by an internal Variable Gain Control (VGC) and then digitized by a 10 bit Analog-to-Digital converter (ADC). For optimal digitization, gain and brightness can be programmed by setting command registers in the camera. Since the IEEE 1394 bus can only handle 8 bit data, the two least significant bits from the ADC are dropped.

The 8 bit pixel data leaving the ADC is transferred to an image buffer. From the buffer, the image data is moved to a 1394 link layer controller where it is assembled into data packets that comply with version 1.20 of the "1394 - based Digital Camera Specification" issued by the 1394 Trade Association. The packets are passed to a 1394 physical layer controller which transmits them isochronously to a 1394 interface board in the host PC. The physical and link layer controllers also handle transmission and receipt of asynchronous data such as programming commands.

The image buffer between the sensor and the link layer controller allows data to be transferred out of the sensor at a rate that is independent of the of the data transmission rate between the camera and the host computer. This ensures that the data transmission rate has no influence on image quality.

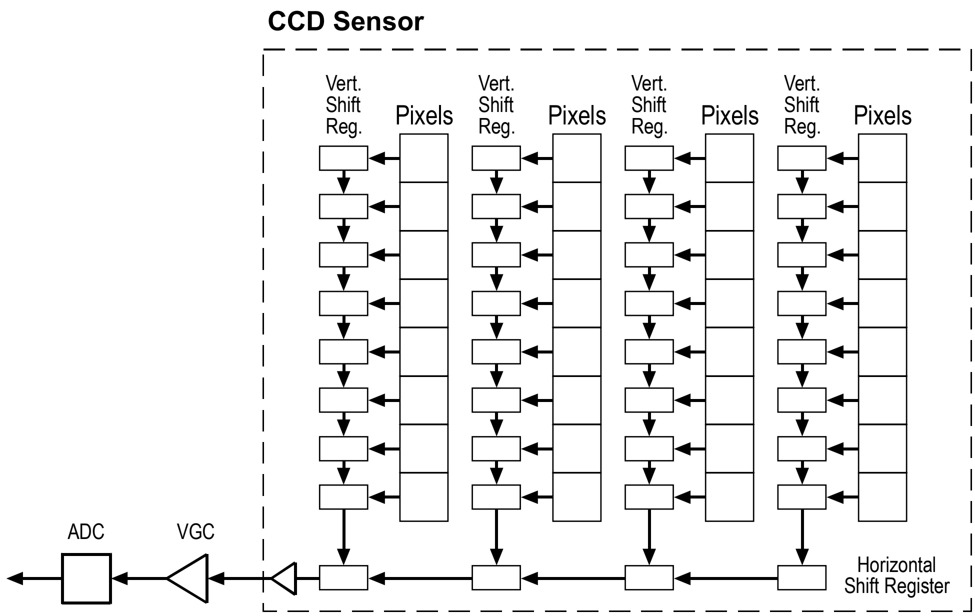


Figure 3-1: Sensor Architecture

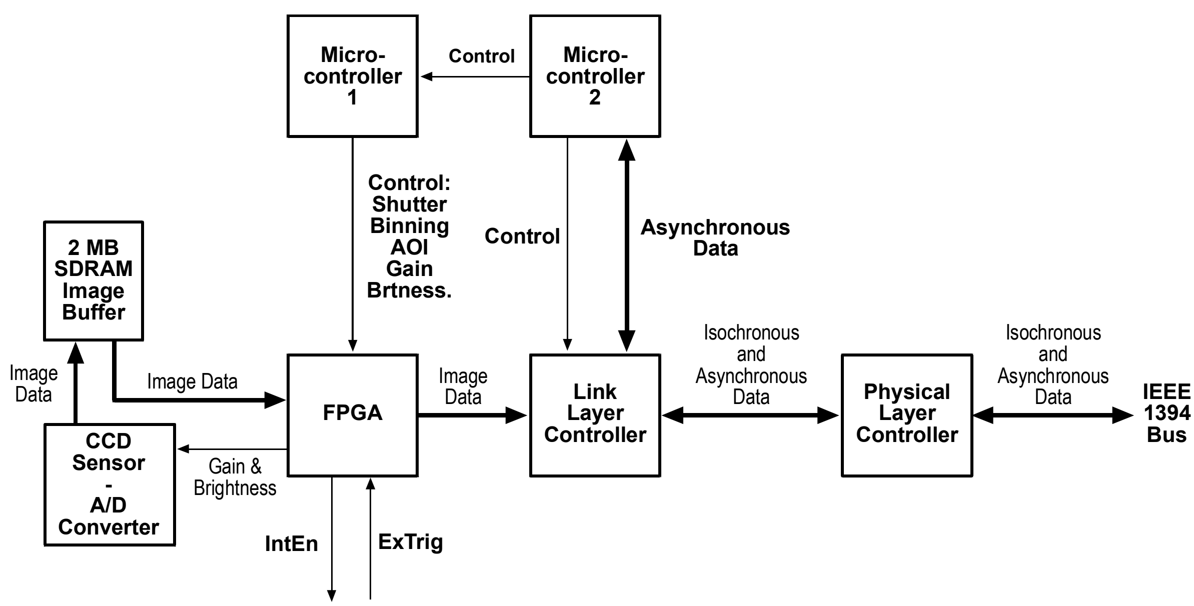


Figure 3-2: Block Diagram

3.2 Exposure Control

3.2.1 Setting the Exposure Time

Exposure time is determined by the value stored in the SHUTTER control register. The value in the register can range from 0 to 4095 (0x000 to 0xFFF). The value in the register represents *n* in the equation: Exposure Time = (*n* + 1) x 20 µs. So, for example, if the value stored in the SHUTTER register is 100 (0x064), the exposure time will be (100 + 1) x 20 µs or 2020 µs.

3.2.2 Controlling Exposure Start via the 1394 Interface

One-Shot Operation

In one-shot operation, the camera exposes and transmits a single frame. Exposure begins when the ONE_SHOT control register is set to 1. Exposure time is determined by the value stored in the SHUTTER control register (see Section 3.2.1).

The ONE_SHOT control register is self cleared when transmission of frame data begins.

> See Section 4.2, Register Write Order, for a complete description of the order in which the camera registers must be written. This applies for one-shot, multi-shot, and continuous-shot operation.

Multi-Shot Operation

In multi-shot operation, the camera exposes and transmits multiple frames. The exposure for the first frame begins when the MULTI_SHOT control register is set to 1. The number of frames that will be transmitted is determined by the value stored in the COUNT_NUMBER field of the control register. The exposure time for each frame is determined by the value stored in the SHUTTER control register (see Section 3.2.1). The start of exposure on the second and subsequent frames is automatically controlled by the camera.

If the camera is operating in video Format 0, Format 1, or Format 2, the rate at which frames will be captured and transmitted is determined by the value stored in the CUR_V_FRM_RATE / REVISION control register.

If the camera is operating in video Format 7, the rate at which frames will be captured and transmitted is determined by the value stored in the BYTE_PER_PACKET control register (see Section 3.12.2).

The MULTI_Shot control register is self cleared when transmission of the last frame begins.

Continuous-Shot Operation

In continuous-shot operation, the camera continuously exposes and transmits frames. The exposure of the first frame begins when the ISO_EN/CONTINUOUS_SHOT control register is set to 1. The exposure time for each frame is determined by the value stored in the SHUTTER control register (see Section 3.2.1). The start of exposure on the second and subsequent frames is automatically controlled by the camera.

If the camera is operating in video Format 0, Format 1, or Format 2, the rate at which frames will be captured and transmitted is determined by the value stored in the CUR_V_FRM_RATE / REVISION control register.

If the camera is operating in video Format 7, the rate at which frames will be captured and transmitted is determined by the value stored in the BYTE_PER_PACKET control register (see Section 3.12.2).

Frame exposure and transmission stop when the ISO_EN/CONTINUOUS_SHOT control register is set to 0.

3.2.3 Controlling Exposure Start with an ExTrig Signal

The external trigger (ExTrig) input signal can be used to control the start of exposure. A rising edge on the ExTrig signal begins exposure. The ExTrig signal can be periodic or non-periodic.

The ExTrig signal must be used in combination with a one-shot, multi-shot, or continuous-shot command. If precise control of exposure start time is desired, you must also monitor the Trigger Ready signal and you must base the timing of the ExTrig signal on the state of Trigger Ready. (See section 3.3 for a detailed explanation of the Trigger Ready signal.)

To enable the external trigger feature and set the camera for rising edge triggering, set the ON_OFF field of the TRIGGER_MODE control register to 1, the Trigger_Polarity field to 1, and the Trigger_Mode field to 0.

ExTrig/One-Shot Operation

In ExTrig/One shot operation, the camera exposes and transmits a single frame. To use this method of operation, follow this sequence:

1. Set the SHUTTER control register for your desired exposure time (see Section 3.2.1).
2. Set the ONE_SHOT control register to 1.
3. Check the state of the TrigRdy signal:
   a) If TrigRdy is high, you can toggle ExTrig when desired.
   b) If TrigRdy is low, wait until TrigRdy goes high and then toggle ExTrig when desired.
4. When ExTrig goes high, exposure will begin. Exposure will continue for the length of time specified in the SHUTTER control register.
5. At the end of the specified exposure time, frame readout and transmission will take place.

The ONE_SHOT control register is self cleared after frame transmission.

> See Section 4.2, Register Write Order, for a complete description of the order in which the camera registers must be written. This applies for one-shot, multi-shot and continuous-shot operation.

ExTrig/Multi-Shot Operation

In ExTrig/Multi shot operation, the camera exposes and transmits multiple frames. The number of frames that will be transmitted is determined by the value stored in the COUNT_NUMBER control register. To use this method of operation, follow this sequence:

1. Set the SHUTTER control register for your desired exposure time (See Section 3.2.1).
2. Set the MULTI_SHOT control register to 1 and set the COUNT_NUMBER control register to the desired number of frames.

3. Check the state of the TrigRdy signal:
   a) If TrigRdy is high, you can toggle ExTrig when desired.
   b) If TrigRdy is low, wait until TrigRdy goes high and then toggle ExTrig when desired.
4. When ExTrig goes high, exposure will begin. Exposure will continue for the length of time specified in the SHUTTER control register.
5. At the end of the specified exposure time, frame readout and transmission will take place.
6. Repeat steps 3, 4, and 5 until you have captured the number of frames specified in the count number register.

The MULTI_SHOT control register is self cleared after transmission of the last frame.

ExTrig/Continuous-Shot Operation

In ExTrig/Continuous-shot operation, the camera continuously exposes and transmits frames. To use this method of operation, follow this sequence:

1. Set the SHUTTER control register for your desired exposure time (see Section 3.2.1).
2. Set the ISO_EN/CONTINUOUS_SHOT control register to 1.
3. Check the state of the TrigRdy signal:
   a) If TrigRdy is high, you can toggle ExTrig when desired.
   b) If TrigRdy is low, wait until TrigRdy goes high and then toggle ExTrig when desired.
4. When ExTrig goes high, exposure will begin. Exposure will continue for the length of time specified in the SHUTTER control register.
5. At the end of the specified exposure time, frame readout and transmission will take place.
6. Repeat steps 3, 4, and 5 each time that you want to capture a frame.
7. Frame exposure and transmission stop when the ISO_EN/CONTINUOUS_SHOT control register is set to 0.

3.2.4 Recommended Methods for Controlling Exposure Start

If a camera user requires close control of exposure start, there are several general guidelines that must be followed:

- the camera should be placed in continuous shot mode.
- the user must use an external trigger signal to start exposure and must set the camera to react to a rising edge of the trigger signal (i.e., active high).
- the user must monitor the trigger ready signal and the integrate enabled signal (see Sections 3.3 and 3.4 for an explanation of these signals).
- a rising edge of the external trigger signal must only occur when the trigger ready signal is high.

Assuming that these general guidelines are followed, the reaction of the camera to a rising external trigger signal will be one of two cases. In case one, the rising edge of ExTrig occurs when the camera <u>is not</u> transferring a captured frame from the sensor to the image buffer. In case two, the rising edge of ExTrig occurs when the camera <u>is</u> transferring a captured frame from the sensor to the image buffer.

Case 1 - Exposure Start When the Camera is not Transferring a Frame

After each exposure is complete, there is a time period of 80.7 ms. during which the captured frame is transferred from the CCD sensor to the camera's image buffer.

If the ExTrig signal rises after this time period has ended as shown in Figure 3-3:

- The start of exposure will occur between 3 and 6 µs after the rise of ExTrig. For a given camera, the delay in the start of exposure will be consistent from frame to frame. (The size of the delay will vary slightly from camera to camera, but will always be in the 3 to 6 µs range.)
- The IntEn signal will rise between 2 and 3 µs after the start of exposure. For a given camera, the delay in the rise of IntEn will be consistent from frame to frame. (The size of the delay will vary slightly from camera to camera, but will always be in the 2 to 3 µs range.)
- The actual length of exposure will be equal to the programmed exposure time plus 4 µs.

To know when frame transfer to the buffer is taking place, the user must monitor the integrate enabled signal. The frame transfer time period begins on the falling edge of the integrate enabled signal and lasts for 80.7 ms.

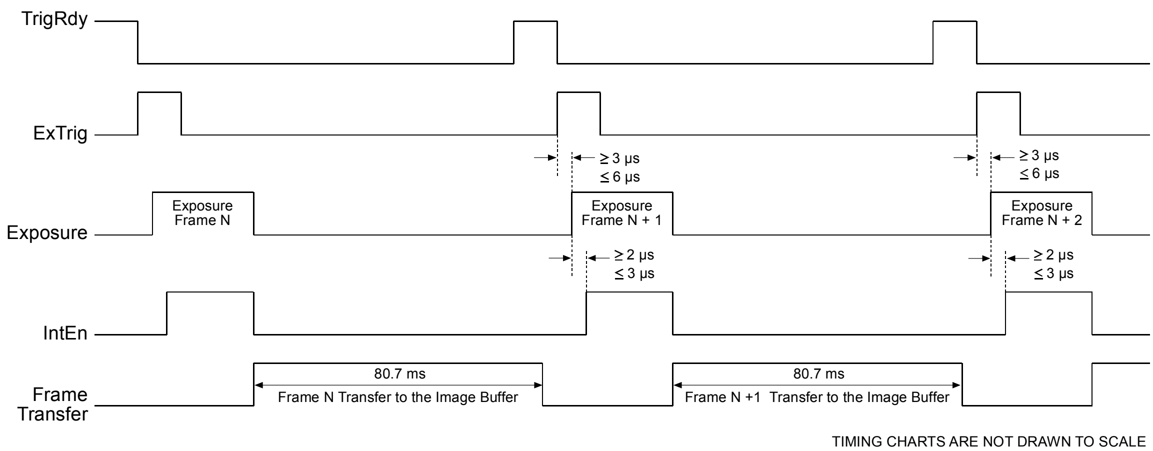


Figure 3-3: Exposure Start After Frame Transfer

The camera can be programmed to react to a rising edge of the ExTrig signal or to a falling edge of the ExTrig signal. We **strongly** recommend that you program the camera to react to the rising edge of the signal (i.e., active high).

If falling edge triggering is used, the time between the falling edge of the ExTrig signal and the actual start of exposure is excessively long (at least 90 µs). This occurs due to the characteristics of the opto-coupler on the camera's ExTrig input.

Case 2 - Exposure Start When the Camera <u>is</u> Transferring a Frame

After each exposure is complete, there is a time period of 80.7 ms. during which the captured frame is transferred from the CCD sensor to the camera's image buffer.

If the ExTrig signal rises during this time period as shown in Figure 3-4:

- The start of exposure will occur between 3 µs and 86 µs after the rise of ExTrig. The delay in the start of exposure will vary from frame to frame but will always fall in the 3 to 86 µs range.[1]
- The IntEn signal will rise between 2 and 3 µs after the start of exposure. For a given camera, the delay in the rise of IntEn will be consistent from frame to frame. (The size of the delay will vary slightly from camera to camera, but will always be in the 2 to 3 µs range.)
- The actual length of exposure will be equal to the programmed exposure time plus 4 µs.

To know when frame transfer to the buffer is taking place, the user must monitor the integrate enabled signal. The frame transfer time period begins on the falling edge of the integrate enabled signal and lasts for 80.7 ms.

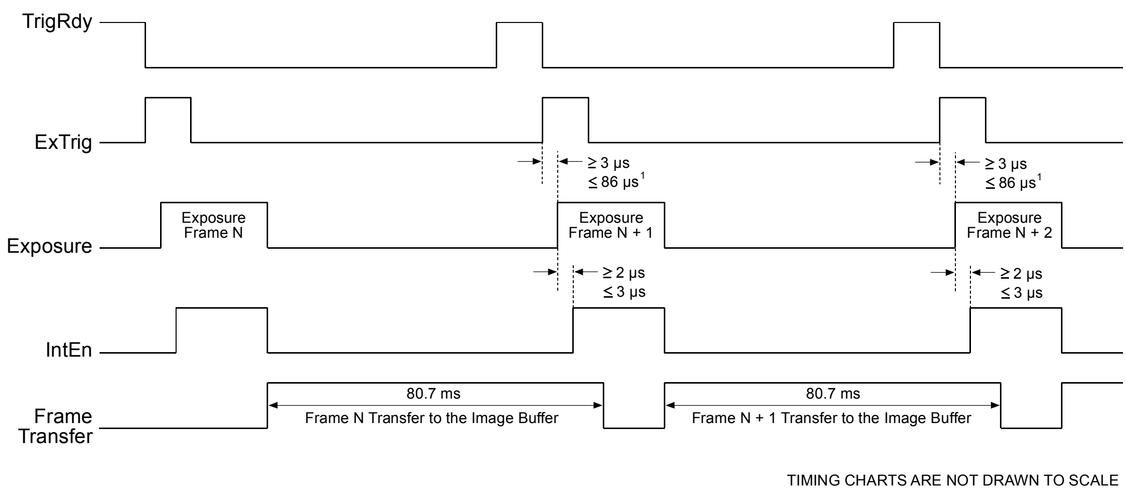


Figure 3-4: Exposure Start During Frame Transfer

[1] This variability in the start of exposure is commonly referred to as an exposure start jitter. It occurs because when the camera is transferring an image, exposure can only start at certain fixed points during the frame transfer process. If an exposure is triggered when the transfer process is very near to one of these fixed points, the exposure start delay can be as little as 3 µs. If an exposure is triggered when the transfer process is very far from one of these fixed points, the start delay can be as much as 86 µs.

If you need very close control of exposure start time, you should trigger exposure start when the camera is not transferring a frame as shown on page 3-6.

The camera can be programmed to react to a rising edge of the ExTrig signal or to a falling edge of the ExTrig signal. We **strongly** recommend that you program the camera to react to the rising edge of the signal (i.e., active high).

If falling edge triggering is used, the time between the falling edge of the ExTrig signal and the start of exposure will be excessively long (at least 90 µs). This occurs due to the characteristics of the opto-coupler on the camera's ExTrig input.

3.3 Trigger Ready Signal

The trigger ready signal is not defined in the 1394 Trade Association Digital Camera Specification. Trigger ready is a special feature of Basler cameras.

One possible way to control the camera is to perform an image exposure followed by charge read out and frame transfer and to wait until frame transfer is complete before beginning the next exposure. This situation is illustrated in Figure 3-5.

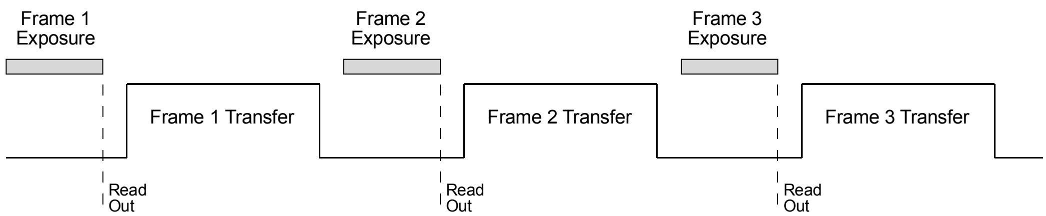


Figure 3-5: Exposure Between Frame Transfers

While the method of control shown above may be useful in many situations, it is not workable if your objective is to achieve maximum frame rate. To achieve maximum frame rate, most of the exposure for each frame must take place while the previous frame is being transferred out of the CCD array. This situation is illustrated in Figure 3-6.

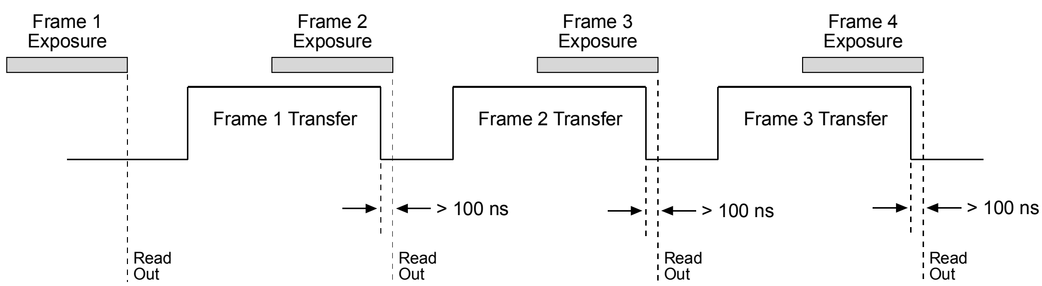


Figure 3-6: Exposure During Frame Transfer

A point to notice when looking at Figure 3-6 is that exposure must not end during frame transfer; the end of exposure for the next frame must occur at least 100 ns after the transfer of the current frame. (For example, the exposure for frame two must end at least 100 ns after frame one transfer is complete.)

This situation poses a problem when you are controlling exposure with an ExTrig signal, that is, how will you know when to toggle the ExTrig signal and begin exposure so that the exposure will end at least 100 ns after the last frame transfer.

This problem is addressed by the trigger ready signal. The trigger ready signal will go high at the earliest moment that you can begin exposure and still be sure that the exposure will end at least 100 ns after the transfer of the last frame.

For better understanding of the use of trigger ready signal, consider an example. Assume that you will set the exposure time to 20 µs for every exposure and that you want to begin exposing as early as possible during transfer of the previous frame. In this case, the trigger ready signal will go high 20 µs before the earliest allowable end of exposure. This situation is illustrated in Figure 3-7.

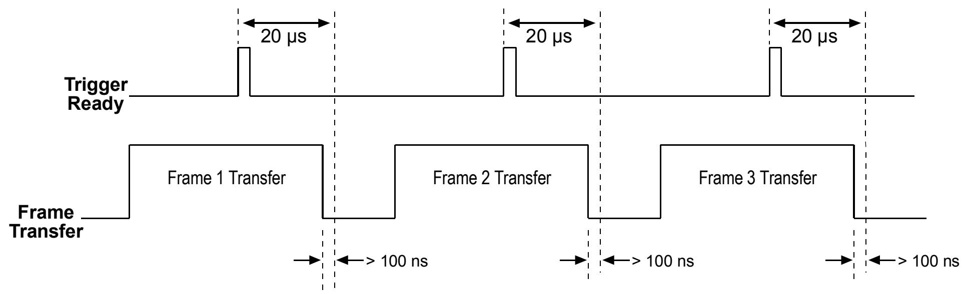


Figure 3-7: Trigger Ready Signal

If you monitor the trigger ready signal, and toggle ExTrig when the trigger ready signal goes high, the exposure will end at the earliest allowable point. Figure 3-8 illustrates how the ExTrig signal should toggle if you want your 20 µs exposure time to overlap frame transfer as much as possible. (Note that the trigger ready signal goes low when exposure starts.)

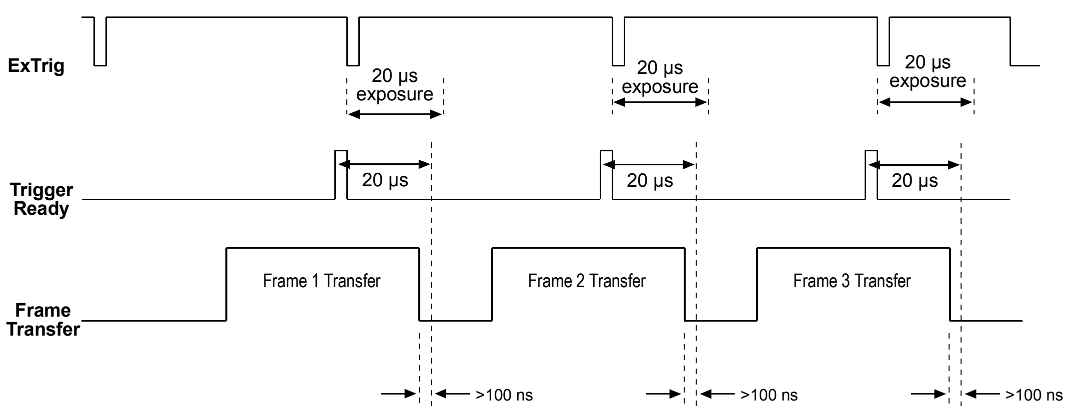


Figure 3-8: Using Trigger Ready to Time the ExTrig Signal

3.3.1 What Happens if you Toggle ExTrig while TrigRdy is Low

As explained above, the trigger ready signal is designed to ensure that exposure ends after the previous frame transfer is complete. But what happens if you toggle ExTrig while the trigger ready signal is low. In this case, the camera will remember that ExTrig has toggled and will delay the start of exposure until the trigger ready signal goes high.

3.4 Integrate Enabled Signal

The Integrate Enabled (IntEn) signal goes high when exposure begins and goes low when exposure ends. This signal is especially useful when you are operating a system where either the camera or the object being imaged is movable.

For example, assume that the camera is mounted on an arm mechanism and that the mechanism can be used to move the camera to view different portions of a product assembly. Typically, you do not want the camera to move during exposure. In this case, you can monitor the IntEn signal to know exactly when exposure is taking place and thus know when to avoid moving the camera.

3.5 Version Information

A101f cameras include an advanced feature called “Extended Versions” that allows the user to read the version numbers of the firmware and several other elements in the camera. The version numbers are contained in an ASCII character string located in the EXTD_VERSIONS advanced features register. The extended versions register and the layout of the information contained in the character string are described in detail on page 4-12.

☝	Extended versions is an advanced feature and may not be supported by the camera driver software that you are using.

3.6 Gain and Brightness

The major components in the camera electronics include: a CCD sensor, a VGC (Variable Gain Control), and an ADC (Analog to Digital Converter). The pixels in the CCD sensor output voltage signals when they are exposed to light. These voltages are amplified by the VGC and transferred to the ADC which converts the voltages to digital output signals.

Two parameters, gain and brightness are associated with the VGC. As shown in Figures 3-9 and 3-10, increasing or decreasing the gain increases or decreases the amplitude of the signal that is input to the ADC. Increasing or decreasing the brightness moves the signal up or down the measurement scale but does not change the signal amplitude.

The default gain and brightness are set so that with optimal lighting and exposure, the linear output range of the CCD sensor maps to the input range of the ADC. Under these conditions, black will produce a gray value of 1 from the ADC and white will produce a gray value of 254.

For most applications, black should have a gray value of 1 and white should have a gray value of 254. Attempt to achieve this by varying exposure and illumination rather than changing the camera's gain. The default gain is the optimal operating point (minimum noise) and should be used if possible.

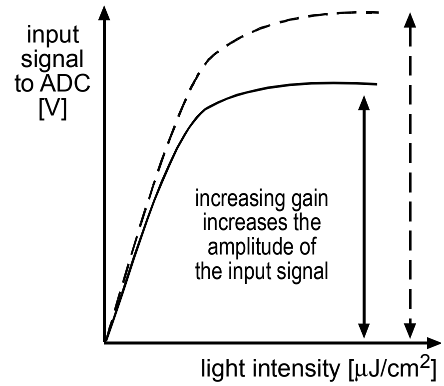


Figure 3-9: Gain

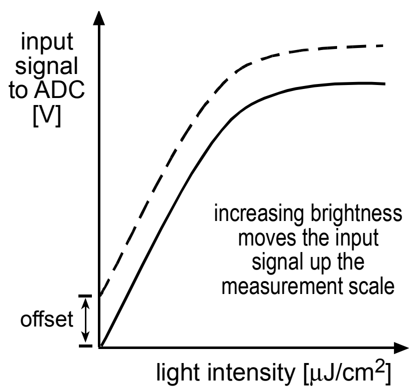


Figure 3-10: Brightness

☝	Because increasing gain increases both signal and noise, the signal to noise ratio does not change significantly when gain is increased.

3.6.1 Gain settings in more detail

The output signals from the pixels in the CCD sensor normally range from 0 Volts when the pixels are exposed to no light to 0.4 Volts when they are exposed to bright light. Within that range, the sensor characteristics are linear. Saturation starts at 0.4 Volts. Further exposure results in a higher sensor output signal but linearity is no longer guaranteed.

The default factory gain is set for an amplification factor of 5.0 (14 dB). At this setting, the sensor's normal linear output range of 0 V - 0.4 V is amplified to 0 V - 2.0 V. The peak-to-peak input range of the ADC is 0 V - 2.0 V. Thus when the gain is at factory default, the amplified output of the sensor maps directly to the input voltage range of the ADC.

Gain is adjustable and can be programmed on a decimal scale that ranges from 0 to 511 (0x000 to 0x1FF). However, only the settings from 0 to 319 (0x000 to 0x13F) are effective. Settings greater than 319 will not increase the gain and should not be used. The settings result in the following amplification:

- 0 = 4.5 dB
- 319 = 34.5 dB
- In between, the change in dB setting is linear.
- The gain can be adjusted in steps of 0.094 dB.

The desired 14 dB default gain is achieved when the gain is programmed to 101 (0x065). You should find that the default gain setting on your camera is near to this value.

Reducing the gain below 101 results in mapping more than the linear operating range of the sensor to the ADC. Increasing the gain to more than 101 maps a smaller portion of the sensor's linear output signal to the ADC.

If you know the decimal number setting for the gain on your camera, the equivalent decibel value can be calculated as follows:

$$dB = \left(\frac{34.5 - 4.5}{319} \times DN \right) + 4.5$$

3.7 Binning

Binning increases the camera's sensitivity to light by summing the charges from adjacent pixels into one pixel. There are three types of binning available: horizontal binning, vertical binning and full binning.

With horizontal binning, pairs of adjacent pixels in each line are summed (see Figure 3-11). With vertical binning, pairs of adjacent pixels from two lines are summed. Full binning is a combination of horizontal and vertical binning in which four adjacent pixels are summed.

When horizontal binning is active, image resolution decreases to 650 pixels (H) by 1030 pixels (V). When vertical binning is active, resolution decreases to 1300 (H) by 515 (V). With full binning, resolution decreases to 650 (H) by 515 (V).

Horizontal binning is enabled by setting the CUR_V_FORMAT control register to 7 and the CUR_V_MODE control register to 1. Vertical binning is enabled by setting the CUR_V_FORMAT control register to 7 and the CUR_V_MODE control register to 2. Full binning is enabled by setting the CUR_V_FORMAT control register to 7 and the CUR_V_MODE control register to 3.

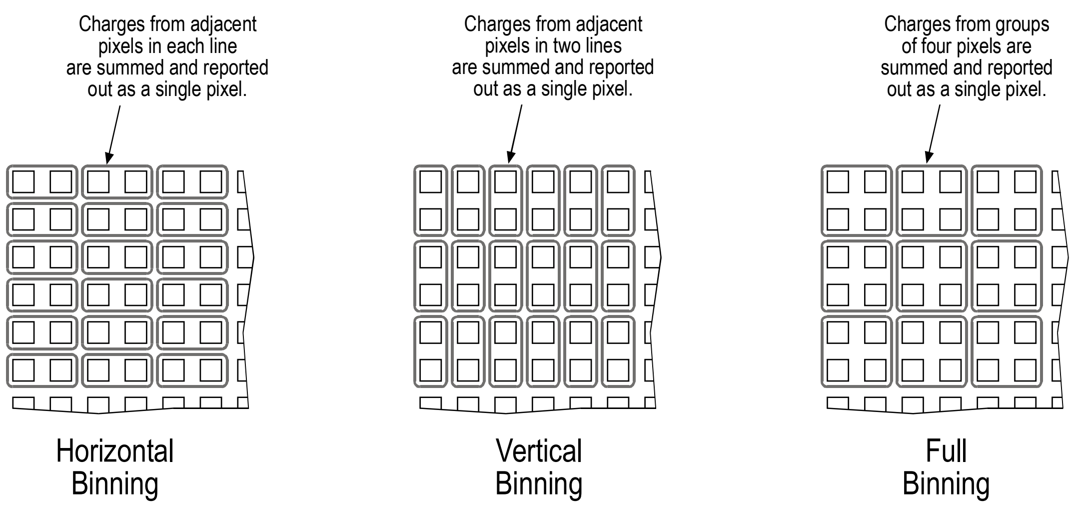


Figure 3-11: Binning

Binning is only available on the **A101f** monochrome camera.

Using horizontal or vertical binning generally increases the camera's sensitivity by up to two times normal. Full binning increases sensitivity up to four times normal. After switching on binning, the image might look overexposed. Reduce the lens aperture, light intensity, or exposure in this case.

With horizontal binning active, frame grabbers often require the information that the horizontal resolution is 650. With vertical binning active, they often require the information that the vertical resolution is 515. With full binning active, they often require the information that the horizontal resolution is 650 and the vertical resolution is 515.

With vertical or full binning active (horizontal binning has no effect), the maximum allowed frame rate increases to 22.89 frames/sec.

3.8 Area of Interest (AOI)

The area of interest (AOI) feature allows you to specify a portion of the CCD array and during operation, only the pixel information from the specified portion of the array is transferred out of the camera.

The area of interest is referenced to the top left corner of the CCD array. The top left corner is designated as column 0 and row 0 as shown in Figure 3-12.

The location and size of the area of interest is defined by declaring a left-most column, a width, a top row and a height. Reference position is the top left corner of the image. For example, suppose that you specify the left column as 10, the width as 16, the top row as 4 and the height as 10. The area of the array that is bounded by these settings is shown in Figure 3-12.

The camera will only transmit pixel data from within the area defined by your settings. Information from the pixels outside of the area of interest is discarded.

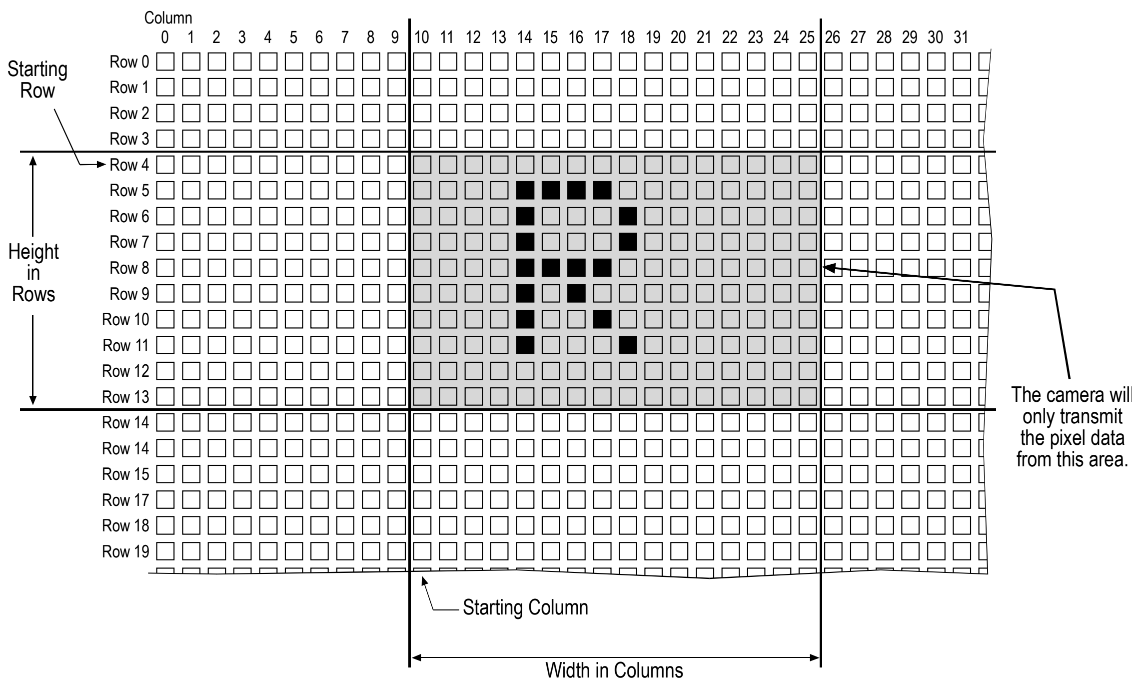


Figure 3-12: Area of Interest

The AOI feature is enabled by setting the CUR_V_FORMAT control register to 7 and the CUR_V_MODE control register to 0. The location of the area of interest is defined by setting a value for the “left” field and a value for the “top” field within the IMAGE_POSITION control register that has been established for Format_7, Mode_0. The size of the area of interest is defined by setting a value for the “width” field and a value for the “height” field within the IMAGE_SIZE control register that has been established for Format_7, Mode_0.

To use the entire CCD array on the **A101f**, set the value for “left” to 0, the value for “top” to 0, the value for “width” to 1300 and the value for “height” to 1030.

☝	On the **A101fc** color camera: the setting for *Left* must be 0 or an even number. the setting for *Top* must be 0 or an even number. the setting for *Width* must be an even number. the setting for *Height* must be an even number. On all cameras, the sum of the setting for *Left* plus the setting for *Width* must not exceed 1300. On all cameras, the sum of the setting for *Top* plus the setting for *Height* must not exceed 1030. On all cameras, the AOI must contain at least 6144 pixels (width x height).

3.8.1 Changes to the Frame Rate With AOI

When the area of interest (AOI) feature is used, the maximum allowed frame rate depends on the number of rows included in the area of interest. The maximum allowed frame rate increases as the number of rows included in the area of interest decreases. The formula below can be used to calculate the maximum allowed frame rate when the AOI feature is used:

$$\text{Frames/sec.} = \frac{1{,}000{,}000\ \mu s}{43\ \mu s + [(1029 - \text{Rows in AOI}) \times 5.44\ \mu s] + [(\text{Rows in AOI} + 1) \times 80.05\ \mu s] + 0.1\ \mu s}$$

Table 3-1 shows the maximum allowed frame rates for a variety of AOI sizes.

Rows in AOI	Highest Frame Rate	Rows in AOI	Highest Frame Rate
1000	12.4 Frames/sec.	500	23.2 Frames/sec.
900	13.7 Frames/sec.	400	28.1 Frames/sec.
800	15.2 Frames/sec.	300	35.5 Frames/sec.
700	17.2 Frames/sec.	200	48.4 Frames/sec.
600	19.8 Frames/sec.	100	75.8 Frames/sec.

Table 3-1: Maximum Allowed Frame Rates

☝	The examples in Table 3-1 assume that you are using the maximum allowed packet size. If you use a smaller packet size, you will not be able to achieve the stated frame rates. See Section 3.12.2 for more details.

3.9 Test Images

The test image mode is used to check the camera's basic functionality and its ability to transmit an image via the video data cable. The test image mode can be used for service purposes and for failure diagnostics. In test mode, the image is generated with a software program and the camera's digital devices and does not use the optics, CCD sensor, VGC, or ADC. Three different test images are available.

Test images are an advanced feature. The test images are enabled by setting the ImageOn field of the TEST_IMAGE advanced features register (see page 4-13). To enable test image one, set the field to 1. To enable test image two, set the field to 2. To enable test image three, set the field to 3. To disable the test image feature, set the field to 0.

When a test image is active, the gain, brightness, and exposure time have no effect on the image.

Test Image one

As shown in Figure 3-13, test image one consists of lines with several gray scale gradients ranging from 0 to 255. If the camera is operating at full 1300 x 1030 resolution when the test images are generated:

- the first line starts with a gray value of 0 for the first pixel,
- the second line starts with a gray value 1 for the first pixel,
- the third line starts with a gray value of 2 for the first pixel, and so on.

(If the camera is operating at a lower resolution when the test images are generated, the basic appearance of the test pattern will be similar to Figure 3-13, but the staring pixel values on each line will not be as described above.)

The mathematical expression for test image one is:

$$\text{grayvalue} = [\, x + y \,]\ \text{MOD256}$$

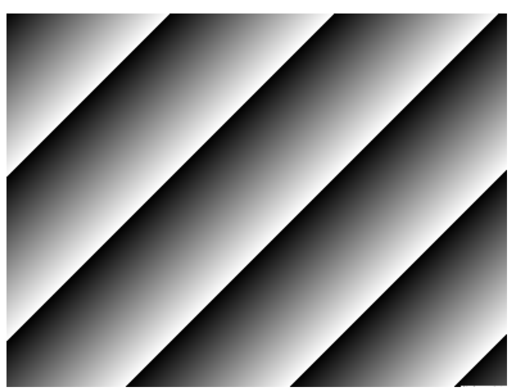


Figure 3-13: Test Image One

Test Image Two

As shown in Figure 3-14, test image two consists of lines with several gray scale gradients ranging from 0 to 255. If the camera is operating at full 1300 x 1030 resolution when the test images are generated:

- lines 1, 2, 3, and 4 start with a gray value of 0 for the first pixel,
- lines 5, 6, 7, and 8 start with a gray value of 1 for the first pixel,
- lines 9, 10, 11, and 12 start with a gray value of 2 on the first pixel, and so on.

(If the camera is operating at a lower resolution when the test images are generated, the basic appearance of the test pattern will be similar to Figure 3-14, but the staring pixel values on each line will not be as described above.)

The mathematical expression for test image two is:

$$\text{grayvalue} = \frac{[\,x + y\,]}{4} \text{ MOD } 256, \quad \text{round off all values}$$

Figure 3-14: Test Image Two

Test Image Three

Test image three (not shown) is similar to test image one, but it is not stationary. The image moves by 1 pixel from right to left whenever a one-shot, multi-shot or continuous-shot command signal is sent to the camera.

☝	Test Images are an advanced feature and may not be supported by the camera driver software that you are using.

3.10 Low Smear

In applications where a CCD sensor is under constant illumination, high-contrast images may show smearing. Smearing is an unwanted effect that converts dark pixels into brighter ones. With the help of the low smear feature on the **A101f**, smearing is reduced on the upper part of the image. The effect of the low smear feature is illustrated in Figure 3-15.

The low smear feature cannot be activated or de-activated. Low smear is active all of the time, however, the feature operates best at lower frame rates.

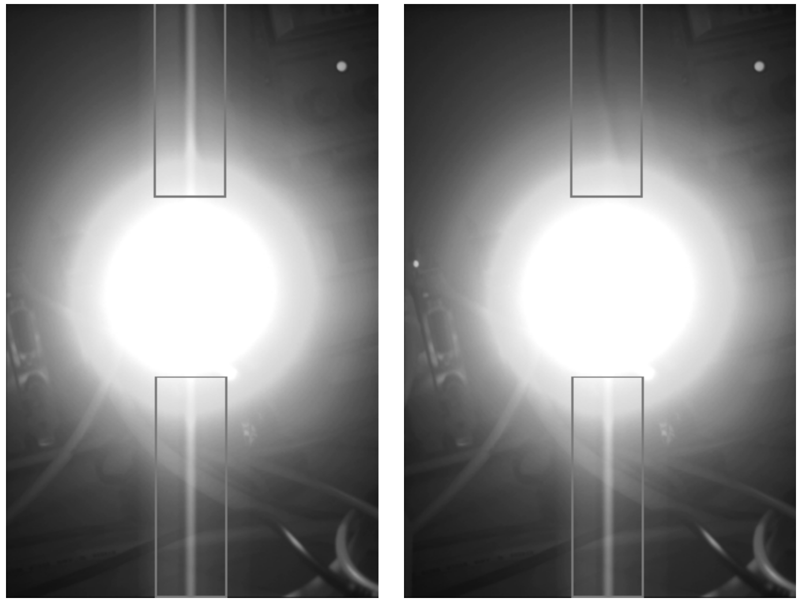


Figure 3-15: Full Smear (left), Low Smear (right)

A two step process must be used to calculate the maximum frame rate that you can use and still see the full effect of the low smear feature. First, you must use this formula to calculate the frame transfer time based on the size of the area of interest (AOI):

$$T(f) = 43\ \mu s + [(1029 - AOIH) \times 5.44\ \mu s] + [(AOIH + 1) \times 80.05\ \mu s] + 0.1\ \mu s$$

where: T(f) = frame transfer time

AOIH = number of rows in the AOI

Second, you must use this formula to calculate the maximum allowed frame:

$$\text{Frames/sec.} \leq \frac{1{,}000{,}000\ \mu s}{T(f) + [(AOIH + AOIT) \times 7.1\ \mu s] + T(e)}$$

where: T(f) = frame transfer time

AOIH = number of rows in the AOI

AOIT = number of rows above the AOI

T(e) = exposure time

To better understand these calculations, let's look at an example. Suppose that you are working with an 800 (H) x 600 (V) area of interest, that there are 215 rows above the AOI and that you want a 2 ms. exposure. The calculations would look like this:

$$T(f) = 43\ \mu s + [\ (1029 - 600) \times 5.44\ \mu s\ ] + [\ (600 + 1) \times 80.05\ \mu s\ ] + 0.1\ \mu s$$

$$T(f) = 50.487\ ms$$

and:

$$\text{Frames/sec.} \leq \frac{1{,}000{,}000\ \mu s}{50.487\ ms + [\ (600 + 215) \times 7.1\ \mu s\ ] + 2\ ms}$$

$$\text{Frames/sec.} = 17.2$$

So in this case, you can run the camera at up to 17.2 frames per second and still see the full effect of the low smear feature.

If the camera's actual frame rate is higher than the maximum allowed frame rate, the smearing will come back. When you exceed the maximum allowed frame rate by a small amount, the upper part of the image will show partial smearing (see Figure 3-16). As the frame rate is increased, the smearing will become worse.

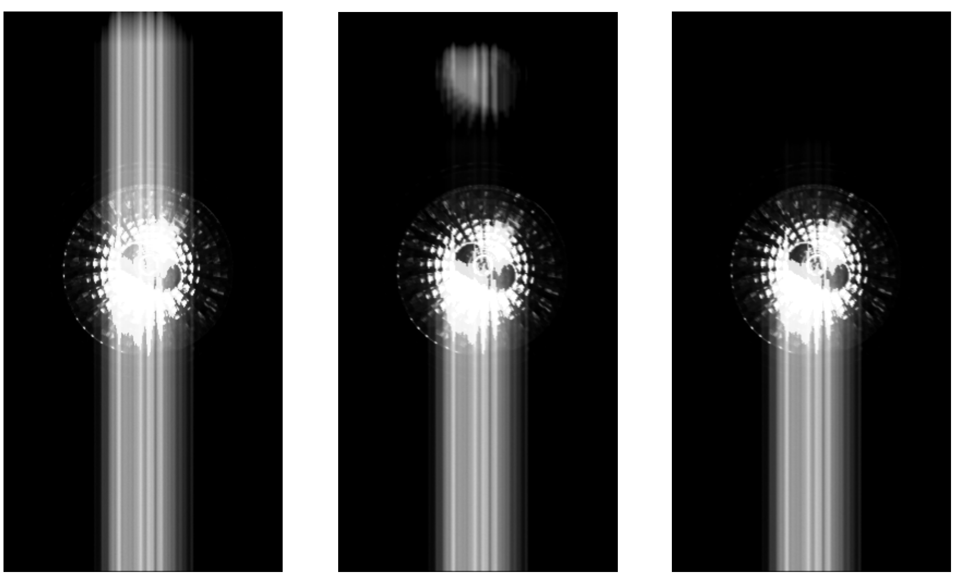


Figure 3-16: Full Smear (left), Partial Smear (middle), Low Smear (right)

3.11 Color Creation in the A101fc

The CCD sensor used in the **A101fc** is equipped with an additive color separation filter known as a Bayer filter. With the Bayer filter, each individual pixel is covered by a micro-lens which allows light of only one color to strike the pixel. The pattern of the Bayer filter used in the **A101fc** is shown in Figure 3-17. As the figure illustrates, within each block of four pixels, one pixel sees only red light, one sees only blue light, and two pixels see only green light. (This combination mimics the human eye's sensitivity to color.)

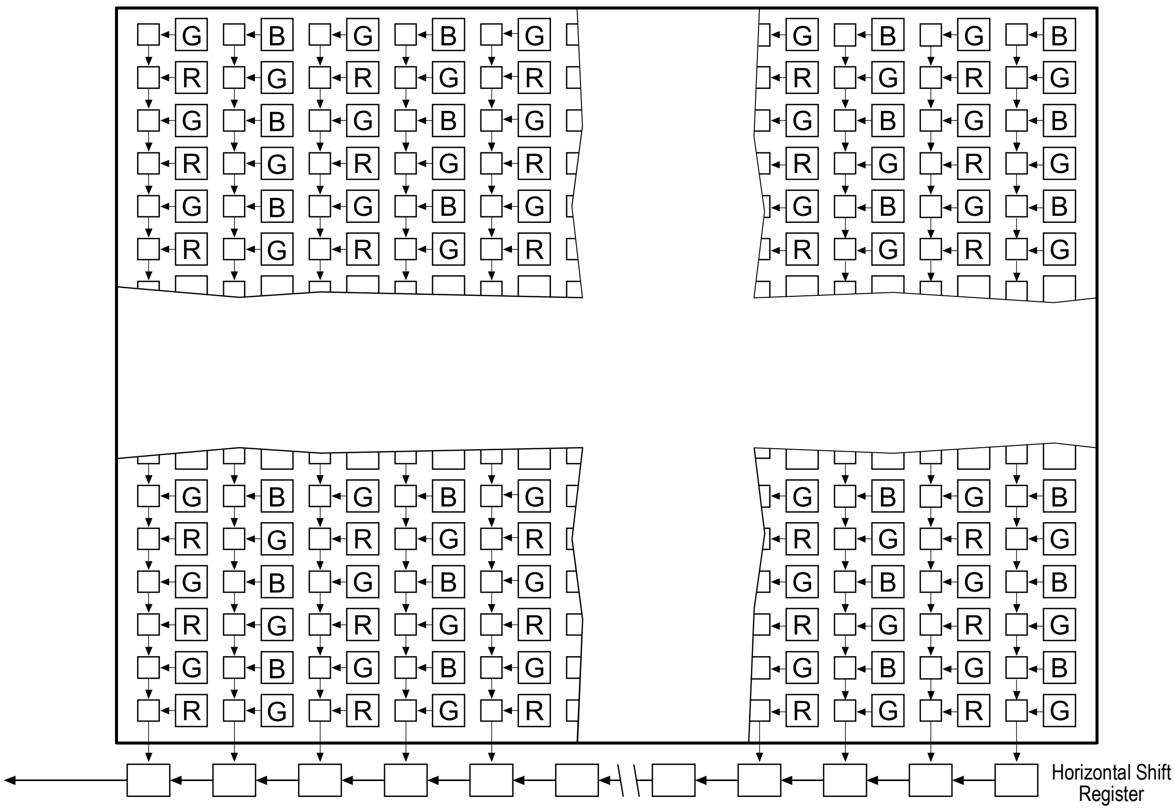


Figure 3-17: Bayer Filter Pattern on the **A101fc**

When an **A101fc** is operating in a color output mode, each pixel goes through a two step conversion process as it exits the sensor and passes through the camera's electronics.

In the first step of the process, an interpolation algorithm is performed to get full RGB data for the pixel. (Because each individual pixel gathers information for only one color, an interpolation must be made from the surrounding pixels to get full RGB data for an individual pixel.)

Since the 1394 Digital Camera Specification requires that color information be transmitted as YUV, the second step of the process is to convert the RGB information to YUV. The conversion algorithm uses the following formulas:

$Y = 0.3\ R + 0.59\ G + 0.11\ B$

$U = -0.168\ R - 0.33\ G + 0.498\ B$

$V = 0.499\ R - 0.421\ G - 0.078\ B$

Once the conversion to YUV is complete, pixels are transmitted from the camera in the YUV (4:2:2) format as defined in Section 2.1.3 *Video Data Payload Structure* in the 1394-based Digital Camera Specification Version 1.20.

> The values for U and for V normally range from -128 to +128. Because the 1394 Digital Camera specification requires that U values and V values be transmitted with unsigned integers, 128 is added to each U value and to each V value before the values are transmitted from the camera. This process allows the values to be transmitted on a scale that ranges from 0 to 256 (for more information, see Section 2.1.4 *Data Structure* in the 1394-based Digital Camera Specification Version 1.20).
>
> As a result of the conversion process, the pixel data for the first line and for the first column is not useful. This data should be discarded.
>
> When an **A101fc** is operating in a YUV (4:2:2) mode, the average number of bits per pixel is 16. This means that the camera will require twice the bandwidth of a camera operating in 8 bit monochrome mode.
>
> The **A101fc** can operate in several YUV (4:2:2) color modes and can also operate in several monochrome 8 bit modes (see Sections 3.12.3 and 3.12.4).

3.11.1 White Balance

White balance capability has been implemented on the **A101fc**. With white balancing, a correction factor can be applied to the U values and to the V values transmitted from the camera.

The U_Value field of the WHITE_BALANCE control register can be used to apply a correction factor to the U values transmitted from the camera. The setting for the field can range from 0 to 255. If the field is set to 0, the image will be less blue. If the field is set to 128, there will be no effect on the image. And if the field is set to 255, the image will be more blue.

The V_Value field of the WHITE_BALANCE control register can be used to apply a correction factor to the V values transmitted from the camera. The setting for the field can range from 0 to 255. If the field is set to 0, the image will be less red. If the field is set to 128, there will be no effect on the image. And if the field is set to 255, the image will be more red.

3.11.2 Using the A101fc in a Monochrome Mode

The **A101fc** color camera is normally used in a YUV (4:2:2) color output mode. The camera can also operate in several 8 bit monochrome output modes. The 1394 Digital Camera Specification indicates that when a color camera is operating in a monochrome mode, the camera should output the Y value for each pixel. The **A101fc** <u>does not</u> operate this way. Instead, it outputs the raw data for each pixel. This allows the camera user to perform color interpolations or other processing algorithms on pixel data that has not been manipulated.

3.11.3 Integrated IR Cut Filter on C-Mount Equipped Cameras

Cameras equipped with a C-mount lens adapter contain an IR cut filter inside of the camera. The location of the filter limits the thread length of the lens that is used on the camera. See Section 5.5 for more details on lens thread length.

Cameras equipped with an F-mount lens adapter do not contain an IR cut filter.

3.12 Available Video Formats, Modes, & Frame Rates

3.12.1 Standard Formats, Modes, and Frame Rates on the A101f Monochrome Camera

The following standard video formats, modes, and frame rates are available on the **A101f**:

Format_0, Mode_5, FrameRate_1 (Mono, 8 bits/pixel, 640 x 480 pixels at 3.75 fps)

Format_0, Mode_5, FrameRate_2 (Mono, 8 bits/pixel, 640 x 480 pixels at 7.5 fps)

Format_0, Mode_5, FrameRate_3 (Mono, 8 bits/pixel, 640 x 480 pixels at 15 fps)

Format_1, Mode_2, FrameRate_2 (Mono, 8 bits/pixel, 800 x 600 pixels at 7.5 fps)

Format_1, Mode_2, FrameRate_3 (Mono, 8 bits/pixel, 800 x 600 pixels at 15 fps)

Format_1, Mode_5, FrameRate_1 (Mono, 8 bits/pixel, 1024 x 768 pixels at 3.75 fps)

Format_1, Mode_5, FrameRate_2 (Mono, 8 bits/pixel, 1024 x 768 pixels at 7.5 fps)

Format_1, Mode_5, FrameRate_3 (Mono, 8 bits/pixel, 1024 x 768 pixels at 15 fps)

Format_2, Mode_2, FrameRate_0 (Mono, 8 bits/pixel, 1280 x 960 pixels at 1.875 fps)

Format_2, Mode_2, FrameRate_1 (Mono, 8 bits/pixel, 1280 x 960 pixels at 3.75 fps)

Format_2, Mode_2, FrameRate_2 (Mono, 8 bits/pixel, 1280 x 960 pixels at 7.5 fps)

3.12.2 Customizable Formats and Modes on the A101f Monochrome Camera

The following customizable video formats and modes are available on the **A101f**:

Format_7, Mode_0

Format_7, Mode_0 is available on the **A101f**. In this format and mode, the camera's output will be mono, 8 bits/pixel.

Format_7, Mode_0 is used to enable and set up the area of interest (AOI) feature described in Section 3.8. The maximum allowed frame rate in this mode depends on the size of the AOI. The formula shown on page 4-15 can be used to calculate the highest allowed frame rate for any size AOI.

When the camera is operating in Format_7, Mode_0, the frame rate can be adjusted by setting the number of bytes that are transmitted in each packet. The number of bytes per packet is set using the BytePerPacket field of the BYTE_PER_PACKET control register that has been established for Format_7, Mode_0.

The value that appears in the MaxBytePerPacket field of the PACKET_PARA_INQ control register will show the maximum allowed setting for the bytes per packet. When the bytes per packet is set to the maximum, the camera will transmit frames at the maximum allowed frame rate for the AOI size you have defined. By default, the bytes per packet are set to the maximum.

The maximum bytes per packet will vary depending on the size of the AOI. This occurs to avoid image buffer under-runs. The rate of image data flowing out of the image buffer must be correctly balanced against the amount of image data entering the buffer.

If you set the bytes per packet to a value lower than the maximum allowed, the camera will transmit frames at a lower rate. The rate is calculated by the formula:

$$\text{Frames/Sec.} = \frac{1{,}000{,}000\ \mu s}{\text{Packets per Frame} \times 125\ \mu s}$$

The value that appears in the UnitBytePerPacket field of the PACKET_PARA_INQ control register will show the minimum allowed setting for the bytes per packet. The bytes per packet must not be set lower than the minimum.

The minimum bytes per packet will vary depending on the size of the AOI. This occurs because of hardware limits on the link layer controller.

Format_7, Mode_1

Format_7, Mode_1 is available on the A101f. In this format and mode, the camera's output will be mono, 8 bits/pixel.

Format_7, Mode_1 is used to enable horizontal binning as described in Section 3.7. The maximum allowed frame rate in this mode is 11.75 frames/sec. The frame rate can be adjusted using the same method as described for Format_7, Mode_0.

Format_7, Mode_2

Format_7, Mode_2 is available on the A101f. In this format and mode, the camera's output will be mono, 8 bits/pixel.

Format_7, Mode_2 is used to enable vertical binning as described in Section 3.7. The maximum allowed frame rate in this mode is 22.89 frames/sec The frame rate can be adjusted using the same method as described for Format_7, Mode_0.

Format_7, Mode_3

Format_7, Mode_3 is available on the A101f. In this format and mode, the camera's output will be mono, 8 bits/pixel.

Format_7, Mode_3 is used to enable full binning as described in Section 3.7. The maximum allowed frame rate in this mode is 22.89 frames/sec. The frame rate can be adjusted using the same method as described for Format_7, Mode_0.

When the camera is operating in Format_7, Mode_0, in Format_7, Mode_1, in Format _7, Mode_2, or in Format_7, Mode_3, the CUR_V_FRAME_RATE control register is not used and has no effect on camera operation.

3.12.3 Standard Formats, Modes, and Frame Rates on the A101fc Color Camera

The following standard video formats, modes, and frame rates are available on the **A101fc**:

Format_0, Mode_1, FrameRate_1 (YUV 4:2:2, 16 bits/pixel, 320 x 240 pixels at 3.75 fps)
Format_0, Mode_1, FrameRate_2 (YUV 4:2:2, 16 bits/pixel, 320 x 240 pixels at 7.5 fps)
Format_0, Mode_1, FrameRate_3 (YUV 4:2:2, 16 bits/pixel, 320 x 240 pixels at 15 fps)

Format_0, Mode_3, FrameRate_1 (YUV 4:2:2, 16 bits/pixel, 640 x 480 pixels at 3.75 fps)
Format_0, Mode_3, FrameRate_2 (YUV 4:2:2, 16 bits/pixel, 640 x 480 pixels at 7.5 fps)
Format_0, Mode_3, FrameRate_3 (YUV 4:2:2, 16 bits/pixel, 640 x 480 pixels at 15 fps)

Format_0, Mode_5, FrameRate_1 (Mono, 8 bits/pixel, 640 x 480 pixels at 3.75 fps)
Format_0, Mode_5, FrameRate_2 (Mono, 8 bits/pixel, 640 x 480 pixels at 7.5 fps)
Format_0, Mode_5, FrameRate_3 (Mono, 8 bits/pixel, 640 x 480 pixels at 15 fps)

Format_1, Mode_0, FrameRate_1 (YUV 4:2:2, 16 bits/pixel, 800 x 600 pixels at 3.75 fps)
Format_1, Mode_0, FrameRate_2 (YUV 4:2:2, 16 bits/pixel, 800 x 600 pixels at 7.5 fps)
Format_1, Mode_0, FrameRate_3 (YUV 4:2:2, 16 bits/pixel, 800 x 600 pixels at 15 fps)

Format_1, Mode_2, FrameRate_2 (Mono, 8 bits/pixel, 800 x 600 pixels at 7.5 fps)
Format_1, Mode_2, FrameRate_3 (Mono, 8 bits/pixel, 800 x 600 pixels at 15 fps)

Format_1, Mode_3, FrameRate_1 (YUV 4:2:2, 16 bits/pixel, 1024 x 768 pixels at 3.75 fps)
Format_1, Mode_3, FrameRate_2 (YUV 4:2:2, 16 bits/pixel, 1024 x 768 pixels at 7.5 fps)
Format_1, Mode_3, FrameRate_3 (YUV 4:2:2, 16 bits/pixel, 1024 x 768 pixels at 15 fps)

Format_1, Mode_5, FrameRate_1 (Mono, 8 bits/pixel, 1024 x 768 pixels at 3.75 fps)
Format_1, Mode_5, FrameRate_2 (Mono, 8 bits/pixel, 1024 x 768 pixels at 7.5 fps)
Format_1, Mode_5, FrameRate_3 (Mono, 8 bits/pixel, 1024 x 768 pixels at 15 fps)

Format_2, Mode_0, FrameRate_0 (YUV 4:2:2, 16 bits/pixel, 1280 x 960 pixels at 1.875 fps)
Format_2, Mode_0, FrameRate_1 (YUV 4:2:2, 16 bits/pixel, 1280 x 960 pixels at 3.75 fps)
Format_2, Mode_0, FrameRate_2 (YUV 4:2:2, 16 bits/pixel, 1280 x 960 pixels at 7.5 fps)

Format_2, Mode_2, FrameRate_0 (Mono, 8 bits/pixel, 1280 x 960 pixels at 1.875 fps)
Format_2, Mode_2, FrameRate_1 (Mono, 8 bits/pixel, 1280 x 960 pixels at 3.75 fps)
Format_2, Mode_2, FrameRate_2 (Mono, 8 bits/pixel, 1280 x 960 pixels at 7.5 fps)

When the **A101fc** camera is operating in a monochrome mode, raw pixel data is transmitted. See Section 3.11.2 for more details.

3.12.4 Customizable Formats and Modes on the A101fc Color Camera

The following customizable video formats and modes are available on the **A101fc**:

Format_7, Mode_0

Format_7, Mode_0 is available on the **A101fc**. When an **A101fc** is operating in Format_7, Mode_0, its output will be monochrome at 8 bits/pixel and the camera will output the raw data for each pixel (see Section 3.11.2). This mode is used to enable and set up the area of interest (AOI) feature described in Section 3.8.

The maximum allowed frame rate in this mode depends on the size of the AOI. The formula shown on page 4-15 can be used to calculate the maximum allowed frame rate for any size AOI.

When the camera is operating in Format_7, Mode_0, the frame rate can be adjusted by setting the number of bytes that are transmitted in each packet. The number of bytes per packet is set using the BytePerPacket field of the BYTE_PER_PACKET control register that has been established for Format_7, Mode_0.

The value that appears in the MaxBytePerPacket field of the PACKET_PARA_INQ control register will show the maximum allowed setting for the bytes per packet. When the bytes per packet is set to the maximum, the camera will transmit frames at the maximum allowed frame rate for the AOI size you have defined. By default, the bytes per packet are set to the maximum.

The maximum bytes per packet will vary depending on the size of the AOI. This occurs to avoid image buffer under-runs. The rate of image data flowing out of the image buffer must be correctly balanced against the amount of image data entering the buffer.

If you set the bytes per packet to a value lower than the maximum allowed, the camera will transmit frames at a lower rate. The rate is calculated by the formula:

$$\text{Frames/Sec.} = \frac{1{,}000{,}000\ \mu s}{\text{Packets per Frame} \times 125\ \mu s}$$

The value that appears in the UnitBytePerPacket field of the PACKET_PARA_INQ control register will show the minimum allowed setting for the bytes per packet. The bytes per packet must not be set lower than the minimum.

The minimum bytes per packet will vary depending on the size of the AOI. This occurs because of hardware limits on the link layer controller.

Format_7, Mode_1

Format_7, Mode_1 is available on the **A101fc**. When an **A101fc** is operating in Format_7, mode_1, its output will be YUV (4:2:2) at an average of 16 bits/pixel. This mode is used to enable and set up the area of interest (AOI) feature described in Section 3.8. The frame rate can be adjusted using the same method as described for Format_7, Mode_0.

☝	When the camera is operating in Format_7, Mode_0 or in Format_7, Mode_1, the CUR_V_FRAME_RATE control register is not used and has no effect on camera operation.

4 Configuring the Camera

The **A101f** is configured by setting status and control registers as described in version 1.20 of the "1394-Based Digital Camera Specification" issued by the 1394 Trade Association. (The specification is available at the 1394 Trade Association's web site: www.1394ta.org.)

If you are creating your own driver to operate the camera, Sections 4.1 through 4.5 provide the basic information that you will need about the registers implemented in the camera along with some information about read/write capabilities.

A fully functional driver is available for Basler IEEE 1394 cameras such as the **A101f**. The Basler BCAM 1394 Driver includes an API that allows a C++ programmer to easily integrate camera configuration and operating functions into your system control software. The driver also includes a Windows® based viewer program that provides camera users with quick and simple tools for changing camera settings and viewing captured images.

The BCAM 1394 Driver is supplied with comprehensive documentation including a programmer's guide and code samples. For more information, visit the Basler web site at: www.basler-vc.com.

4.1 Block Read and Write Capabilities

The camera supports block reads but not block writes. Block writes are rejected by the camera.

> Do not block read registers that are not present. Use the inquiry registers to find out what registers are present and see the tables on the following pages which describe all implemented registers.

4.2 Register Write Order

Whenever the camera is powered on or is initialized, the registers must be written in the following sequence:

INITIALIZE (optional)

ISO_Channel

CUR_V_FORMAT

CUR_V_MODE

IMAGE_POSITION (Only when using Format 7)

IMAGE_SIZE (Only when using Format 7)

BYTE_PER_PACKET (Only when using Format 7)

CUR_V_FRAME_RATE (For formats other than Format 7)

TRIGGER_MODE

All other registers in any order

ONE_SHOT, MULTI_SHOT, or CONTINUOUS_SHOT

4.3 Changing the Video Format setting

Whenever the Current Video Format setting is changed, you must also do the following:

If the CUR_V_FORMAT is changed to Format 0, you must also write the CUR_V_MODE and the CUR_V_FRM_RATE.

If the CUR_V_FORMAT is changed to Format 1, you must also write the CUR_V_MODE and the CUR_V_FRM_RATE.

If the CUR_V_FORMAT is changed to Format 2, you must also write the CUR_V_MODE and the CUR_V_FRM_RATE.

If the CUR_V_FORMAT is changed to Format 7, you must also write the CUR_V_MODE, the IMAGE_POSITION, the IMAGE_SIZE and the BYTES_PER_PACKET. (See Section 3.12.2 and 3.12.4 for more information on setting the Bytes per Packet in Format 7).

4.4 Implemented Registers

A list of all registers implemented in the A101f appears below.

The base address for all camera control registers is:

Bus_ID, Node_ID, FFFF F0F0 0000

This address is contained in the configuration ROM in the camera unit directory. The offset field in each of the tables is the byte offset from the above base address.

Camera Initialize Register

Offset	Name	Notes
000h	INITIALIZE	

Inquiry Register for Video Format

Offset	Name	Notes
100h	V_FORMAT_INQ	

Inquiry Registers for Video Mode

Offset	Name	Notes
180h	V_MODE_INQ_0 (Format 0)	
184h	V_MODE_INQ_1 (Format 1)	
188h	V_MODE_INQ_2 (Format 2)	
18Ch ... 194h	Reserved	
198h	V_MODE_INQ_6 (Format 6)	
19Ch	V_MODE_INQ_7 (Format 7)	

Inquiry Registers for Video Frame Rate and the Base Address of the Video Mode Command and Status Registers for the Scalable Image Size Format

Offset	Name	Notes
200h	V_RATE_INQ_0_0 (Format_0, Mode_0)	
204h	V_RATE_INQ_0_1 (Format_0, Mode_1)	
208h	V_RATE_INQ_0_2 (Format_0, Mode_2)	
20Ch	V_RATE_INQ_0_3 (Format_0, Mode_3)	
210h	V_RATE_INQ_0_4 (Format_0, Mode_4)	
214h	V_RATE_INQ_0_5 (Format_0, Mode_5)	
218h ... 21Fh	Reserved	
220h	V_RATE_INQ_1_0 (Format_1, Mode_0)	
224h	V_RATE_INQ_1_1 (Format_1, Mode_1)	
228h	V_RATE_INQ_1_2 (Format_1, Mode_2)	
22Ch	V_RATE_INQ_1_3 (Format_1, Mode_3)	
230h	V_RATE_INQ_1_4 (Format_1, Mode_4)	
234h	V_RATE_INQ_1_5 (Format_1, Mode_5)	
238h ... 23Fh	Reserved	
240h	V_RATE_INQ_2_0 (Format_2, Mode_0)	
244h	V_RATE_INQ_2_1 (Format_2, Mode_1)	
248h	V_RATE_INQ_2_2 (Format_2, Mode_2)	
2E0h	V_CSR_INQ_7_0	
2E4h	V_CSR_INQ_7_1	
2E8h	V_CSR_INQ_7_2	
2ECh	V_CSR_INQ_7_3	

Inquiry Register for Basic Functions

Offset	Name	Notes
400h	BASIC_FUNC_INQ	

Inquiry Registers for Feature Presence

Offset	Name	Notes
404h	Feature_Hi_Inq	
408h	Feature_Lo_Inq	
480h	Advanced_Feature_Inq	

Inquiry Registers for Feature Elements

Offset	Name	Notes
500h	BRIGHTNESS_INQ	
504h	AUTO_EXPOSURE_INQ	
508h	SHARPNESS_INQ	
50Ch	WHITE_BAL_INQ	
510h	HUE_INQ	
514h	SATURATION_INQ	
518h	GAMMA_INQ	
51Ch	SHUTTER_INQ	
520h	GAIN_INQ	
524h	IRIS_INQ	
528h	FOCUS_INQ	
52Ch	TEMPERATURE_INQ	
530h	TRIGGER_INQ	
580h	ZOOM_INQ	
584h	PAN_INQ	
588h	TILT_INQ	
58Ch	OPTICAL_FILTER_INQ	
5C0h	CAPTURE_SIZE_INQ	
5C4h	CAPTURE_QUALITY_INQ	

Status and Control Registers for the Camera

Offset	Name	Notes
600h	CUR_V_FRAME_RATE	
604h	CUR_V_MODE	
608h	CUR_V_FORMAT	
60Ch	ISO_CHANNEL	
610h	Camera_Power	Has no effect
614h	ISO_EN Continuous Shot	
618h	Memory_Save	Has no effect
61Ch	One_Shot / Multi-Shot	
620h	Mem_Save_Ch	Has no effect
624h	Cur_Mem_Ch	Has no effect

Status and Control Registers for Features

Offset	Name	Notes
800h	BRIGHTNESS	
804h	AUTO_EXPOSURE	Has no effect
808h	SHARPNESS	Has no effect
80Ch	WHITE_BALANCE	When using an **A101fc** in a YUV output mode, this register can be used to apply a correction factor to the U value for each pixel and to the V value for each pixel. See Section 3.11.1 for more details.
810h	HUE	Has no effect
814h	SATURATION	Has no effect
818h	GAMMA	Has no effect
81Ch	SHUTTER	Exposure time = (shutter value + 1) x 20 µs
820h	GAIN	The gain can be set in a range from 0 to 511 (0x000 to 0x1FF). However, settings above 319 (0x13F) have no effect. The effective range of gain settings is 0 to 319 (0x000 to 0x13F). See Section 3.6.1 for more information.
824h	IRIS	Has no effect
828h	FOCUS	Has no effect
82Ch	TEMPERATURE	Has no effect
830h	TRIGGER_MODE	Only trigger mode 0 is available. We **strongly** recommend that the trigger input polarity be set for high active (1).

Video Mode Control and Status Registers for Format_7

The base address for each Format_7, Mode_0 camera control register is:

Bus_ID, Node_ID, FFFF F1F0 0000

This address is contained in the Format_7 section of the "Inquiry Registers for Video Frame Rate and Base Address of the Video Mode Command and Status Registers for the Scalable Image Size Format." A register has been prepared for each video mode that is Format_7, Mode_x.

The offset field in each of the tables is the byte offset from the above base address.

Video Mode Control and Status Registers for Format_7, Mode_0

Offset	Name	Notes
000h	MAX_IMAGE_SIZE_INQ	
004h	UNIT_SIZE_INQ	
008h	IMAGE_POSITION	
00Ch	IMAGE_SIZE	
010h	COLOR_CODING_ID	
014h	COLOR_CODING_INQ	
034h	PIXEL_NUMBER_INQ	
038h	TOTAL_BYTES_HI_INQ	
03Ch	TOTAL_BYTES_LO_INQ	
040h	PACKET_PARA_INQ	
044h	BYTE_PER_PACKET	TOTAL_BYTES_LO_INQ / BYTE_PER_PACKET must be ≤ 4095.

The base address for each Format_7, Mode_1 camera control register is:

Bus_ID, Node_ID, FFFF F1F0 0100

This address is contained in the Format_7 section of the “Inquiry Registers for Video Frame Rate and Base Address of the Video Mode Command and Status Registers for the Scalable Image Size Format.” A register has been prepared for each video mode that is Format_7, Mode_x.

The offset field in each of the tables is the byte offset from the above base address.

Video Mode Control and Status Registers for Format_7, Mode_1

Offset	Name	Notes
100h	MAX_IMAGE_SIZE_INQ	
104h	UNIT_SIZE_INQ	
108h	IMAGE_POSITION	
10Ch	IMAGE_SIZE	
110h	COLOR_CODING_ID	
114h	COLOR_CODING_INQ	
134h	PIXEL_NUMBER_INQ	
138h	TOTAL_BYTES_HI_INQ	
13Ch	TOTAL_BYTES_LO_INQ	
140h	PACKET_PARA_INQ	
144h	BYTE_PER_PACKET	TOTAL_BYTES_LO_INQ / BYTE_PER_PACKET must be ≤ 4095.

The base address for each Format_7, Mode_2 camera control register is:

Bus_ID, Node_ID, FFFF F1F0 0200

This address is contained in the Format_7 section of the “Inquiry Registers for Video Frame Rate and Base Address of the Video Mode Command and Status Registers for the Scalable Image Size Format.” A register has been prepared for each video mode that is Format_7, Mode_x.

The offset field in each of the tables is the byte offset from the above base address.

Video Mode Control and Status Registers for Format_7, Mode_2

Offset	Name	Notes
200h	MAX_IMAGE_SIZE_INQ	
204h	UNIT_SIZE_INQ	
208h	IMAGE_POSITION	
20Ch	IMAGE_SIZE	
210h	COLOR_CODING_ID	
214h	COLOR_CODING_INQ	
234h	PIXEL_NUMBER_INQ	
238h	TOTAL_BYTES_HI_INQ	
23Ch	TOTAL_BYTES_LO_INQ	
240h	PACKET_PARA_INQ	
244h	BYTE_PER_PACKET	TOTAL_BYTES_LO_INQ / BYTE_PER_PACKET must be ≤ 4095.

The base address for each Format_7, Mode_3 camera control register is:

Bus_ID, Node_ID, FFFF F1F0 0300

This address is contained in the Format_7 section of the “Inquiry Registers for Video Frame Rate and Base Address of the Video Mode Command and Status Registers for the Scalable Image Size Format.” A register has been prepared for each video mode that is Format_7, Mode_x.

The offset field in each of the tables is the byte offset from the above base address.

Video Mode Control and Status Registers for Format_7, Mode_3)

Offset	Name	Notes
300h	MAX_IMAGE_SIZE_INQ	
304h	UNIT_SIZE_INQ	
308h	IMAGE_POSITION	
30Ch	IMAGE_SIZE	
310h	COLOR_CODING_ID	
314h	COLOR_CODING_INQ	
334h	PIXEL_NUMBER_INQ	
338h	TOTAL_BYTES_HI_INQ	
33Ch	TOTAL_BYTES_LO_INQ	
340h	PACKET_PARA_INQ	
344h	BYTE_PER_PACKET	TOTAL_BYTES_LO_INQ / BYTE_PER_PACKET must be ≤ 4095.

4.5 Advanced Features

☝	The advanced features control and status registers are vendor unique and are subject to change.

4.5.1 Advanced Features Access Register

The base address for the Advanced Features Access register is:

Bus_ID, Node_ID, FFFF F2F0 0000

This address is contained in the Advanced_Feature_Inq register of the “Inquiry register for feature presence” section.

The offset field in each of the tables is the byte offset from the above base address.

Advanced Features Access Register

Offset	Name	Notes
000h	ADV_FEATURE_ACCESS	

4.5.2 Advanced Features Registers

The base address for the advanced features registers is:

Bus_ID, Node_ID, FFFF F2F0 0000

The offset field in each of the tables is the byte offset from the above base address.

Inquiry Register for Extended Version Information

Offset	Name	Field	Bit	Description
1010h	EXTD_VERSIONS_INQ	Presence (Read only)	[0]	Presence of this feature
		---	[1..7]	Reserved
		Length (Read only)	[8..15]	Specifies the length in quadlets of the “String” field in the Version Information register (see below).
		---	[16..31]	Reserved

Extended Versions Information Register

Offset	Name	Field	Bit	Description
1014h	EXTD_VERSIONS	String (Read only)	[n Bytes]	An ASCII character string that includes the software version numbers for the camera. The length of this string field is equal to the number of quadlets given in the "Length" field of the Inquiry Register for Version Information (see page 4-11).

The layout of the information in the string field of the Extended Version Information register is as follows:

aaaa,bbbb-cc,dddd-ee,ffff-gg

aaaa = the overall version number of the camera

bbbb = the firmware version for microcontroller 1

cc = the layout version for the registers accessible via the 1394 bus

dddd = the FPGA firmware version

ee = the layout version for the registers in the FPGA

ffff = the firmware version for microcontroller 2

gg = the layout version of the registers in microcontroller 2

If the string does not fill the entire allocated field length, it will be padded with 0x00 at the end of the string.

Status and Control Register for Test Images

This advanced features register can be used to control the operation of the camera's test image feature (see Section 3.9).

Offset	Name	Field	Bit	Description
0098h	TEST_IMAGE	Presence_Inq (Read only)	[0]	Presence of this feature 0: N/A 1: Available
		---	[1..7]	Reserved
		Image_Inq_1 (Read only)	[8]	Presence of test image 1 0: N/A 1: Available
		Image_Inq_2 (Read only)	[9]	Presence of test image 2 0: N/A 1: Available
		Image_Inq_3 (Read only)	[10]	Presence of test image 3 0: N/A 1: Available
		Image_Inq_4 (Read only)	[11]	Presence of test image 4 0: N/A 1: Available
		Image_Inq_5 (Read only)	[12]	Presence of test image 5 0: N/A 1: Available
		Image_Inq_6 (Read only)	[13]	Presence of test image 6 0: N/A 1: Available
		Image_Inq_7 (Read only)	[14]	Presence of test image 7 0: N/A 1: Available
		---	[15]	Reserved
		Image_On (Read/write)	[16..18]	0: No test image active 1: Test image 1 active 2: Test image 2 active 3: Test image 3 active
		---	[19..31]	Reserved

5 Mechanical Considerations

5.1 Camera Dimensions

The camera housing for the **A101f** is manufactured with high precision. Planar, parallel, and angular sides guarantee precise mounting with high repeatability.

The **A101f** camera is equipped with four M4 mounting holes on the front and two M4 mounting holes on each side as indicated in Figure 5-1.

Caution!

To avoid collecting dust on the sensor, mount a lens on the camera immediately after unpacking it.

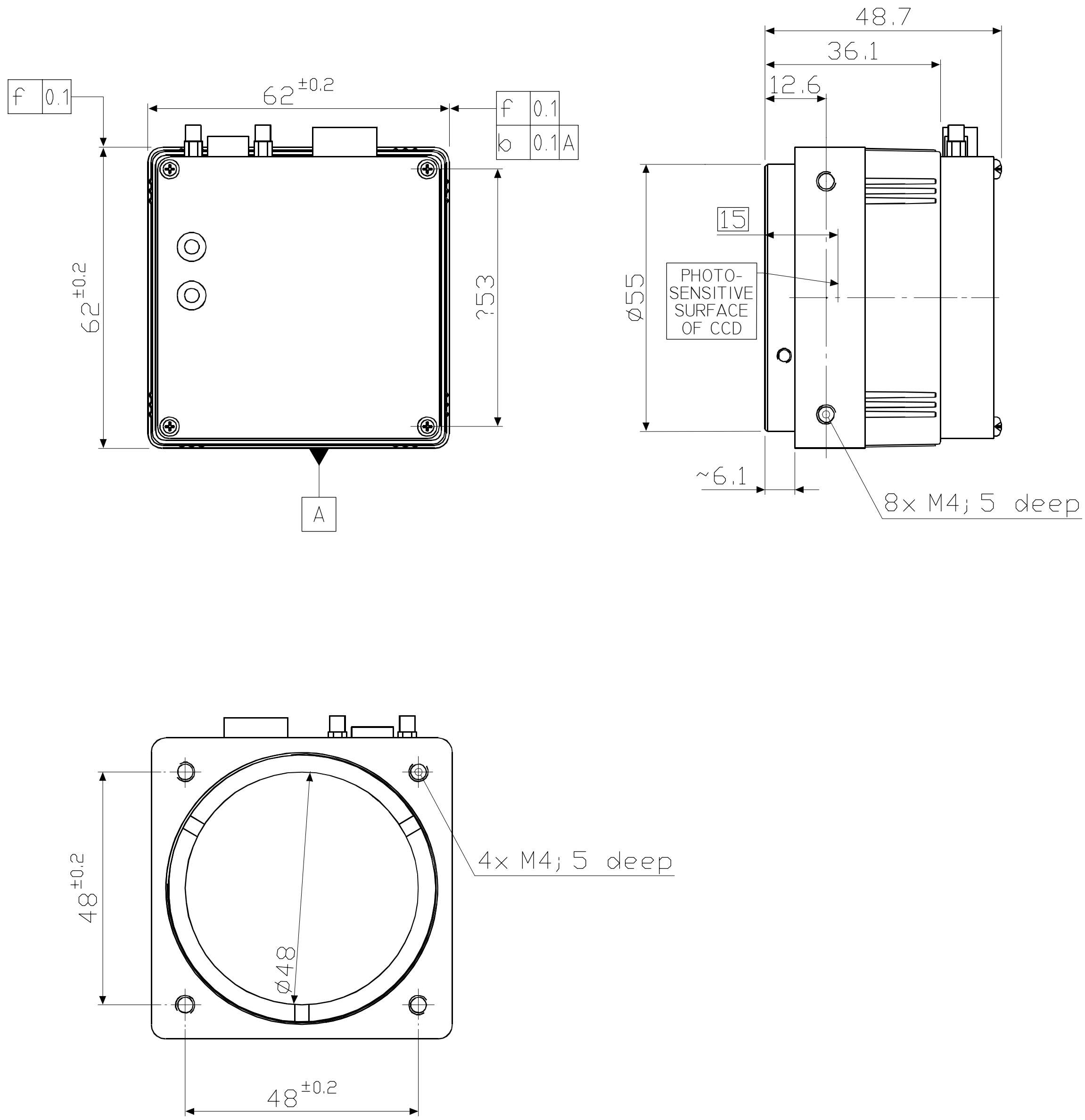


Figure 5-1: **A101f** Mechanical Dimensions (in mm)

5.2 C-Mount Adapter Dimensions

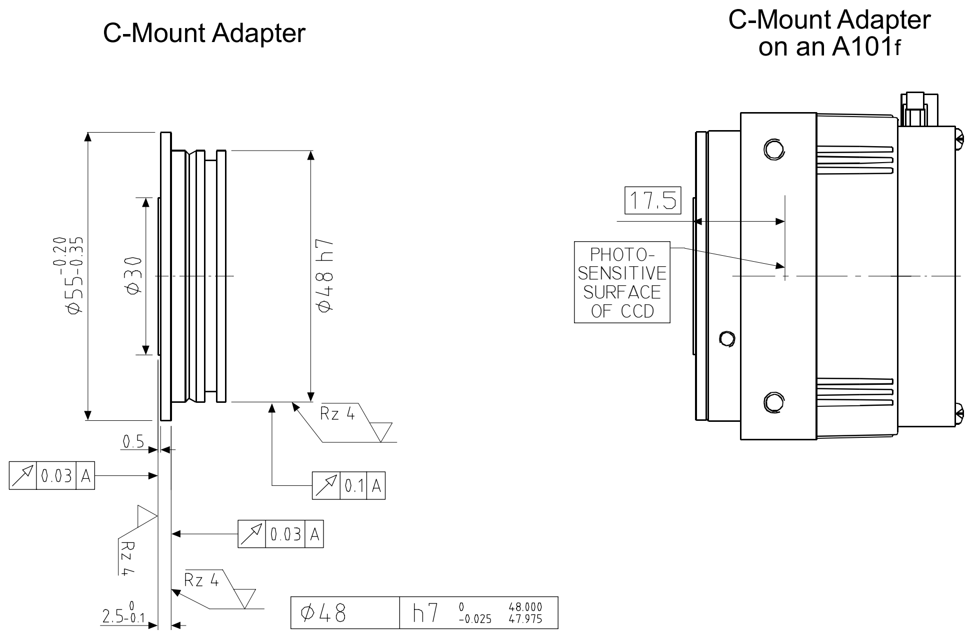


Figure 5-2: C-Mount Adapter Dimensions (in mm)

5.3 F-Mount Adapter Dimensions

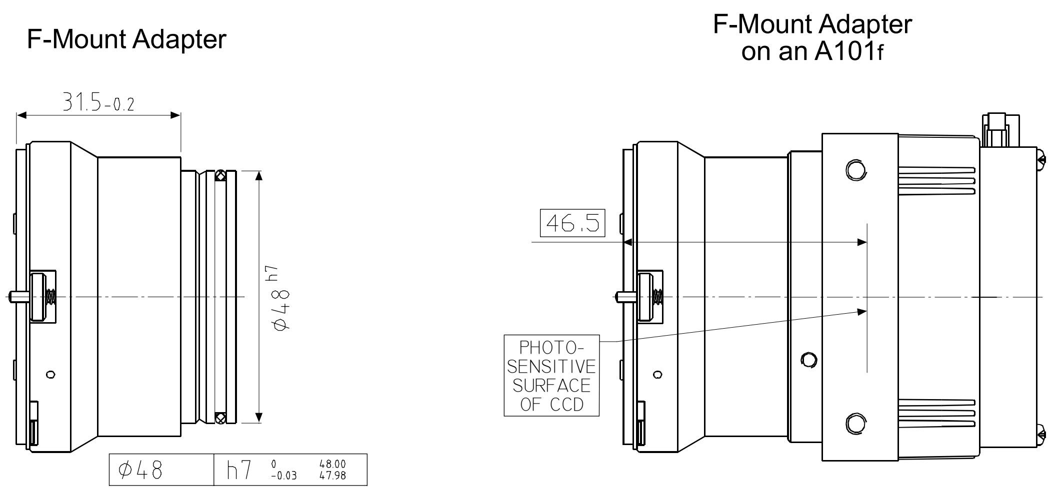


Figure 5-3: F-Mount Adapter Dimensions (in mm)

5.4 Positioning Accuracy of the Sensor Chip

On the A101f, the tolerance for the positioning of the sensor's image area to the camera housing is ± 0.3 mm in the horizontal and vertical directions. Rotational positioning accuracy is as shown in Figure 5-4. Reference position is the center of the camera housing.

Since the translational and rotational positioning tolerances depend on each other, the worst case of maximum rotational and horizontal/vertical mis-positioning cannot occur at the same time.

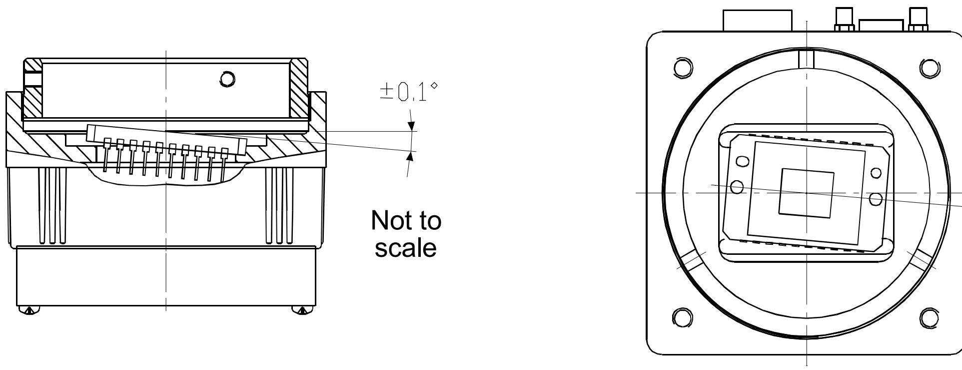


Figure 5-4: A101f Rotational Positioning Accuracy

5.5 Maximum Lens Thread Length on A101fc

Caution!

When a C-mount lens is used on an A101fc, the thread length on the lens must be less than 7.5 mm. If a lens with a longer thread length is used, the camera will be damaged and will no longer operate.

As shown in Figure 5.5, when a C-mount lens is used on an A101fc, the thread length on the lens must be less than 7.5 mm. A101fc cameras equipped with a C-mount lens adapter have an internal IR cut filter. If a lens with a longer thread length is used, the IR cut filter will be damaged or destroyed and the camera will no longer operate.

Cameras equipped with F-mount lens adapters do not have an internal IR cut filter.

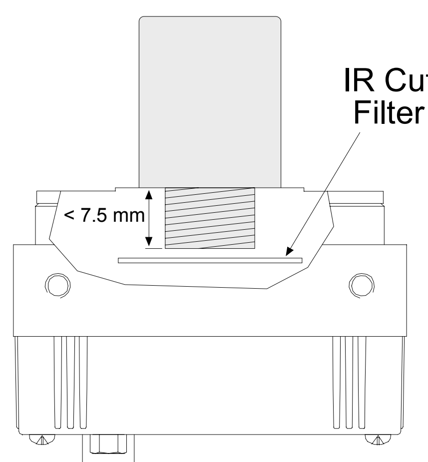


Figure 5-5: C-mount Lens Thread

6 Troubleshooting

6.1 Fault Finding Using Camera LEDs

6.1.1 Yellow LED

The A101f regularly performs self tests. Detected errors are signaled by blinking of the yellow LED on the back of the camera. The number of pulses indicate the detected error. If several error states are present, the yellow LED outputs the error codes in succession.

See Table 6-1 for the description of the pulses.

LED	Camera Condition
On Continuous	The camera is OK.
3 pulses	ExTrig has not changed state for 5 seconds or longer. If you are not using an ExTrig signal, this indication is normal and should be ignored.
6 pulses	The default camera configuration settings could not be loaded. Please contact Basler technical support.
8 pulses	The FPGA could not be configured. Please contact Basler technical support.

Table 6-1: LED States

6.1.2 Green LED

The green LED on the back of the camera is used to indicate whether power is being supplied to the camera. When the green LED is out, it means that no power is present. When the green LED is lit, it means that power is present.

Keep in mind that the circuit used to light the green LED does not perform a range check. If power to the camera is present but it is out of range, the LED may be lit but the camera will not operate properly.

Revision History

Doc. ID Number	Date	Changes
DA039101	6-Feb.-2001	Initial release.
DA039102	18-Apr.-2001	Made numerous small changes to grammar and phrasing. Added connector information in Section 2.1.3. Added ripple specification to Table 1-1 and Section 2.3. Added Section 3.10 containing information on the low smear feature. This feature is available on cameras with FPGA firmware version 2.17 or higher. Version 2.17 firmware will be included in cameras manufactured after May 1, 2001. Added Section 4.6 containing information about how to access firmware version numbers.
DA039103	25-July-2001	Updated the camera model information in Section 1.1. Moved the information about color creation in the **A101fc** to a separate section (Section 3.11) and added information about YUV output, white balance, and using a color camera in monochrome modes. The YUV output and white balance features are available on color cameras with an ID number of 1XXX13053 or higher. Updated the note box on page 3-13 to indicate that binning is only available on monochrome cameras. Corrected the content of the note box at the top of page 3-15. Updated the list of available output formats and modes in Section 3.12. Updated the note for register 80CH on page 4-6. Removed the chapter on camera installation from this manual. The installation information now appears only in the **A101f** Installation Guide.
DA039104	20-May-2002	Corrected the device information in Section 2.2.3 and Figure 2-3. Updated the exposure control information in Section 3.2.3 to specify the use of rising edge triggering. Deleted the detailed timing explanations from Sections 3.2.2 and 3.2.3. Added Section 3.2.4 containing information about recommended methods for exposure start control. Updated Figure 3-12 in Section 3.8 and added information about minimum AOI size to the note box. Corrected the descriptions of test image one and test image two in Section 3.9. Corrected Figure 3-17 in Section 3.11. Added information about the BCAM driver to page 4-1. Updated the information about the advanced features registers in Section 4.5.

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