BASLER A601f-HDR

USER'S MANUAL

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BASLER

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.

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1 Introduction

1.1 Documentation Applicability

This User's Manual applies to cameras with a firmware ID number of 19.

Cameras with a lower or a higher firmware ID number may have fewer features or have more features than described in this manual. Features on cameras with a lower or a higher firmware ID number may not operate exactly as described in this manual.

An easy way to see the firmware ID number for an **A601f-HDR** camera is by using the BCAM Viewer included with the Basler BCAM 1394 driver. To see the firmware ID number:

1. Attach your camera to a computer equipped with the BCAM 1394 driver.
2. Double click the BCAM Viewer icon on your desktop or click Start ⇒ All Programs ⇒ Basler Vision Technologies ⇒ BCAM 1394 ⇒ BCAM Viewer. The viewer program window will open.
3. Find the camera name in the Bus Viewer panel that appears on the left side of the window and click on the camera name.
4. Click on the  icon in the tool bar at the top of the window.
5. A properties window similar to the one shown in Figure 1-1 will open. Use the figure as a guide to find the firmware ID number.

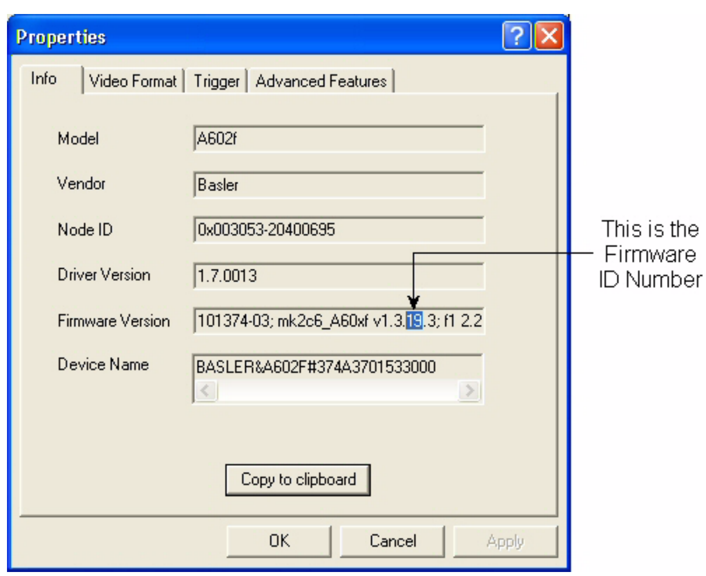

Figure 1-1: BCAM Properties Window

ⓘ	You can also access the firmware ID number by using the Extended Version Information smart feature. See Section 5.7.7 for more information.

1.2 Performance Specifications

Category	Specification
Sensor Type	Micron MT9V403 - 1/2 inch, CMOS, Global Shutter
Pixels	656 (H) x 491 (V)
Pixel Size	9.9 µm (H) x 9.9 µm (V)
Max. Frame Rate (at full resolution)	60 fps in 8 bit output modes 30 fps in 16 bit output modes (frame rate is lower when the HDR feature is used)
Video Output Formats	Mono 8 (8 bits/pixel) Mono 16 (16 bits/pixel - up to 16 bits effective) Vendor Specific 0 (16 bits/pixel) * Pseudo YUV 4:2:2 (16 bits/pix avg.) ** * See page 3-19 and Section 6.3.2 for more details. ** See Section 3.8.1 for more details.
Gain and Brightness	Programmable via IEEE 1394 bus
Exposure Time Control	Programmable via IEEE 1394 bus
Synchronization	External via External Trigger signal
Power Requirements	+8.0 to +36.0 VDC (+12 VDC nominal), < 1% ripple 1.7 W max @ 12 VDC (typical) supplied via 1394 cable
I/O Electrical Characteristics	Inputs: opto-isolated, 5 VDC nominal, 10 mA nominal Outputs: opto-isolated, 2 to 35 VDC maximum forward voltage, 100 mA max collector current See Sections 2.4.1 and 2.4.2 for more details.
Max. Cable Lengths	1394: 4.5 m I/O: 10 m See Section 2.2 for more details.
Lens Adapter	C-mount
Housing Size (L x W x H)	Without lens adapter: 59.0 mm x 44 mm x 29 mm With C-mount adapter: 67.3 mm x 44 mm x 29 mm
Weight	< 100g (typical)
Conformity	CE, FCC

Table 1-1: **A601f-HDR** Performance Specifications

1.3 Camera Models

Currently, only one model of the **A601f-HDR** is available. The camera is monochrome.

1.4 Spectral Response

The spectral response for the **A601f-HDR** is shown in Figure 1-2.

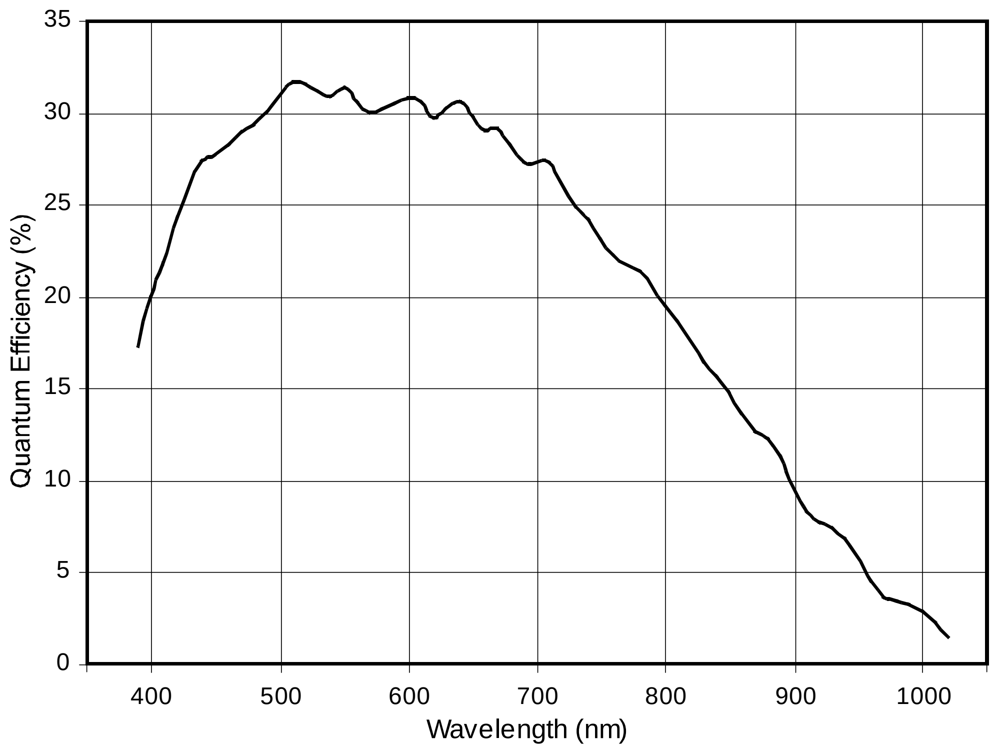

Figure 1-2: **A601f-HDR** Spectral Response

ⓘ	The spectral response curve excludes lens characteristics and light source characteristics.

1.5 Environmental Requirements

1.5.1 Temperature and Humidity

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

1.5.2 Ventilation

Allow sufficient air circulation around the camera to prevent internal heat build-up in your system and to keep the housing temperature below 50° C. Additional cooling devices such as fans or heat sinks are not normally required but should be provided if necessary.

1.6 Precautions

To ensure that your warranty remains in force:

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

Transport the camera in its original packaging only. Do not discard the packaging.

Cleaning

Avoid cleaning the surface of the CMOS sensor if possible. If you must clean it, use a soft, lint free cloth dampened with a small quantity of high quality window cleaner. Because electrostatic discharge can damage the CMOS 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 **A601f-HDR** is interfaced to external circuitry via an IEEE 1394 socket and a 10 pin RJ-45 jack located on the back of the housing. Figure 2-1 shows the location of the two connectors.

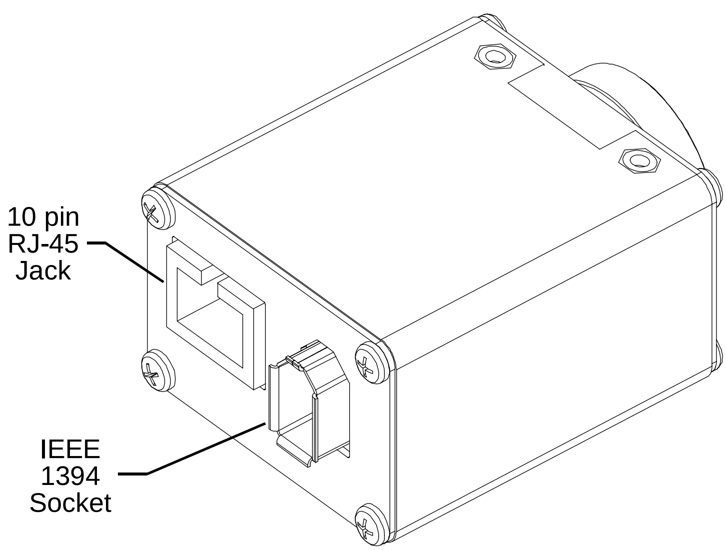

Figure 2-1: Camera Connectors

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
1	Power Input (+8.0 to +36.0 VDC)
2	DC Gnd
3	TPB -
4	TPB +
5	TPA -
6	TPA +

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

The RJ-45 jack is used to interface the external trigger, integrate enabled, and trigger ready signals. The pin assignments for the jack are shown in Table 2-2.

Pin	Designation	Use
1	Output 3 -	Reserved for future use
2	Output 2 -	Reserved for future use
3	Output 1 -	Trigger Ready Output (-)
4	Output 0 -	Integrate Enabled Output (-)
5	Input 0 +	External Trigger Input (+)
6	In Gnd Comm	Common ground for all inputs
7	Out VCC Comm	Common VCC for all outputs
8	Input 2 +	Reserved for future use
9	Input 1 +	Reserved for future use
10	Input 3 +	Reserved for future use

Table 2-2: Pin Assignments for the RJ-45 jack

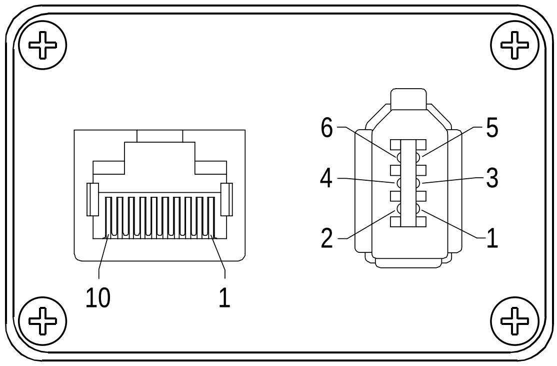

Figure 2-2: **A601f-HDR** Pin Numbering

ⓘ	The camera housing is connected to the cable shields and coupled to signal ground through an RC network (see Figure 2-3 for more details).

2.1.3 Connector Types

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

The 10-pin connector on the camera is an RJ-45 jack.

⚠	**Caution!** The plug on the cable that you attach to the camera's RJ-45 jack must have 10 pins. Use of a smaller plug, such as one with 8 pins or 4 pins, can damage the pins in the RJ-45 jack on the camera.

2.2 Cables

The maximum length of the IEEE 1394 cable used between the camera and the adapter in your PC or between the camera and a 1394 hub is 4.5 meters as specified in the IEEE 1394 standard. Standard, shielded IEEE 1394 cables must be used.

The maximum length of the I/O cable is at least 10 meters. The cable must be shielded and must be constructed with twisted pair wire. Close proximity to strong magnetic fields should be avoided.

2.3 Camera Power

Power must be supplied to the camera via the IEEE 1394 cable. Nominal input voltage is +12.0 VDC, however, the camera will operate properly on any input voltage from +8.0 VDC to +36.0 VDC as specified in the IEEE 1394 standard. Maximum power consumption for the **A601f-HDR** is 1.7 W at 12 VDC. Ripple must be less than 1%.

Caution!

Use only standard IEEE 1394 connectors.

The polarity of the input power to the camera must be as shown in Table 2-1. **Do not** reverse the input power polarity. Reversing the polarity will damage the camera.

2.4 Video Data and Control Signals

2.4.1 Input Signals

2.4.1.1 ExTrig: Controls Exposure Start (Input 0)

Input 0 is designed to receive an external trigger (ExTrig) signal that can be used to control the start of exposure. For more detailed information on using the ExTrig signal to control exposure, see Section 3.2.4.

As shown in Figure 2-3, the input for the ExTrig signal is opto-isolated. The nominal input voltage for the LED in the opto-coupler is 5.0 V (± 1.0 V). The input current for the LED is 5 to 15 mA with 10 mA recommended.

For the ExTrig input, a current between 5 and 15 mA means a logical one. A current of less than 0.1 mA means a logical zero.

ⓘ	As stated above, the nominal input voltage for the LED on each input is +5 VDC. If a 560 Ohm resistor is added to the positive line for an input, the input voltage can be 12 VDC. If a 1.2 or 1.5 kOhm resistor is added to the positive line for an input, the input voltage can be 24 VDC.

2.4.2 Output Signals

2.4.2.1 IntEn: Indicates that Exposure is Taking Place (Output 0)

Output 0 is an integration enabled (IntEn) signal that indicates when exposure is taking place. The IntEn signal will be high during exposure and low when exposure is not taking place. See Section 3.4 for more information on the IntEn signal.

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

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

2.4.2.2 TrigRdy: Indicates that Exposure Can Begin (Output 1)

Output 1 is a trigger ready (TrigRdy) signal that goes high to indicate the earliest point at which exposure start for 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 minimum forward voltage is 2 V, the maximum forward voltage is 35 V, the maximum reverse voltage is 6 V, and the maximum collector current is 100 mA.

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

2.4.2.3 Pixel Data

Pixel data is transmitted as isochronous data packets according to version 1.30 of the “1394 - based Digital Camera Specification” (DCAM) issued by the 1394 Trade Association (see the trade association’s web site: www.1394ta.org). The first packet of each frame is identified by a 1 in the sync bit of the packet header.

Pixel Data Transmission Sequence

Pixel data is transmitted in the following sequence:

- Row 0/Pixel 0, Row 0/Pixel 1, Row 0/Pixel 2 ... Row 0/Pixel 654, Row 0/Pixel 655.
- Row 1/Pixel 0, Row 1/Pixel 1, Row 1/Pixel 2 ... Row 1/Pixel 654, Row 1/Pixel 655.
- Row 2/Pixel 0, Row 2/Pixel 1, Row 2/Pixel 2 ... Row 2/Pixel 654, Row 2/Pixel 655.
- and so forth.

2.4.3 IEEE 1394 Device Information

The **A601f-HDR** uses an IEEE 1394a - 2000 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).

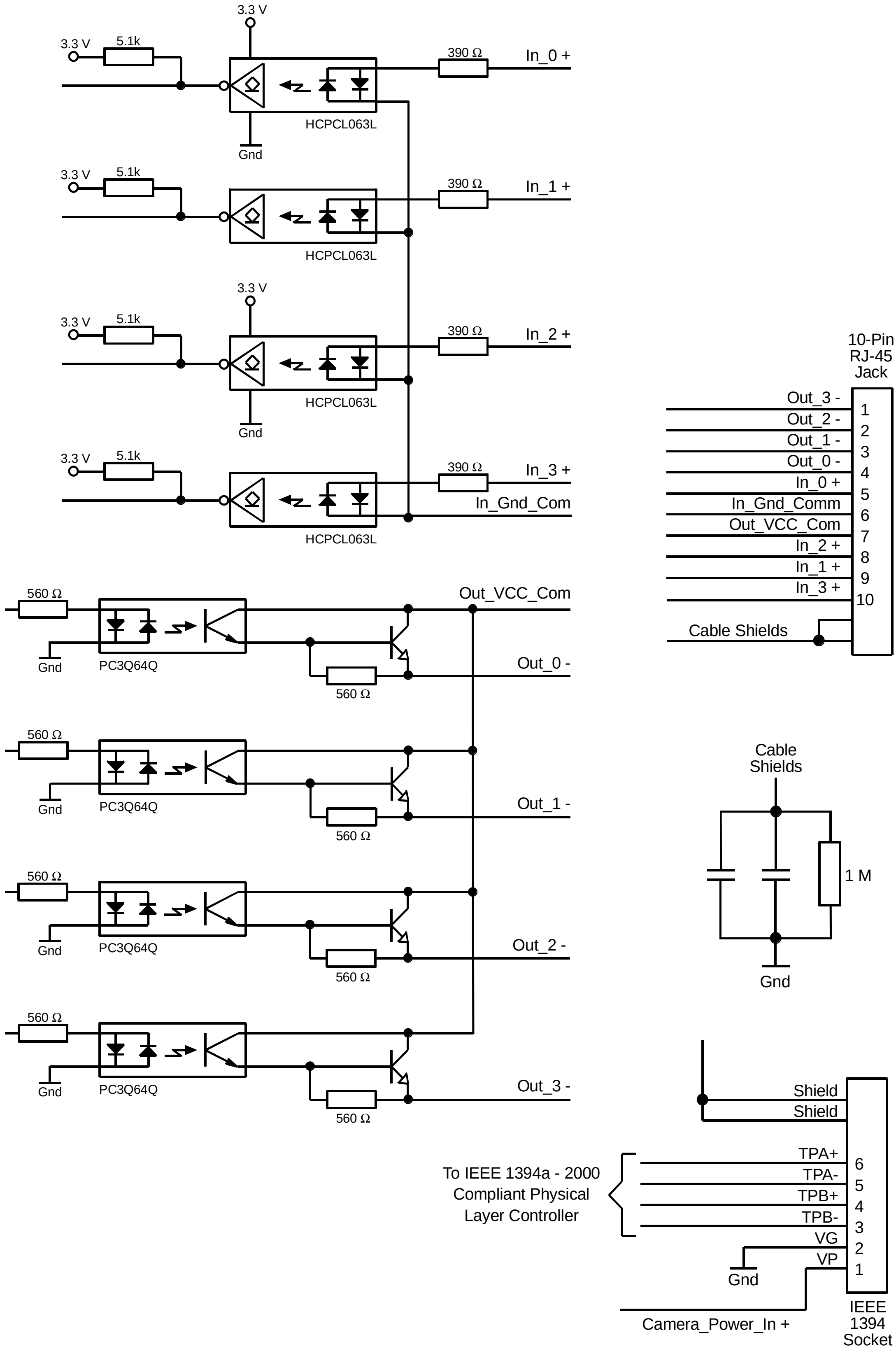

Figure 2-3: I/O Schematic

3 Basic Operation and Standard Features

3.1 Functional Description

3.1.1 Overview

A601f-HDR area scan cameras employ a CMOS-sensor chip which provides features such as a full frame shutter and electronic exposure time control.

Normally, exposure time and charge readout are controlled by values transmitted to the camera's control registers via the IEEE 1394 interface. Control registers are available to set exposure time and frame rate. There are also control registers available to set the camera for single frame capture or 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 a rising ExTrig signal and the camera is set for the programmable exposure mode, exposure begins when the trigger signal goes high 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 each of the sensor's light-sensitive elements (pixels) to a pixel memory (see Figure 3-1). As the charges are moved out of the pixels and into the pixel memories, they are converted to voltages. There is a separate memory for each pixel. Because the sensor has memories that are separate from the pixels, exposure of the next image can begin while the sensor is reading out data from the previously captured image.

The pixel memories can be connected to a bus and there is one bus per vertical column. For readout, the pixel memories are addressed row-wise by closing a switch that connects each pixel memory in the addressed row to the column buses. As the voltages leave the column buses, they are amplified, an offset is applied, and they are digitized by the ADCs. A variable gain control and a 10 bit, analog-to-digital converter (ADC) are attached to the end of each column bus.

From the column buses, the digitized signals enter a horizontal output register. The 10 bit digital video data is then clocked out of the output register, through an FPGA, and into an image buffer.

The data leaves the image buffer and passes back through the FPGA to a 1394 link layer controller where it is assembled into data packets that comply with version 1.30 of the "1394 - based Digital Camera Specification" (DCAM) 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.

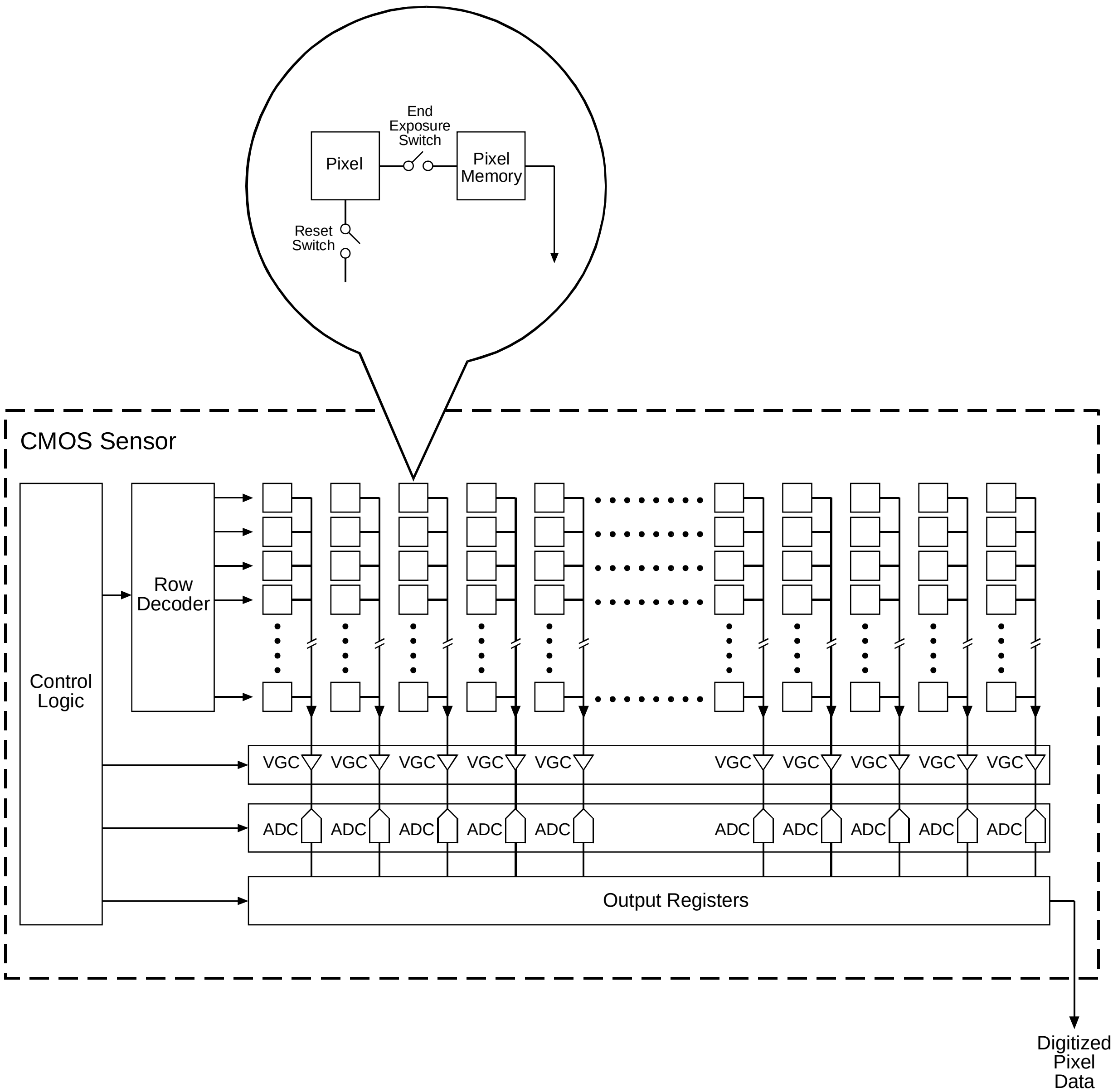

Figure 3-1: **A601f-HDR** Sensor Architecture

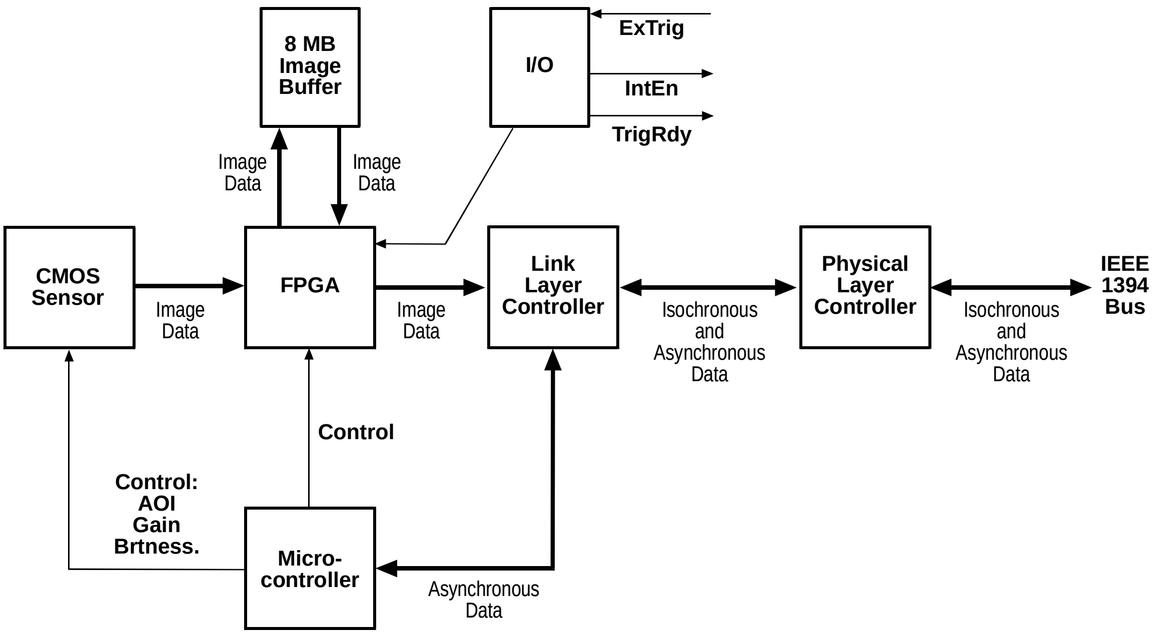

Figure 3-2: Block Diagram

3.2 Exposure Control

3.2.1 Setting the Exposure Time

Exposure time is determined by the value stored in the Shutter control register (see page 4-7). The value in the register can range from 1 to 4095 (0x001 to 0xFFF). The value in the register represents *n* in the equation: Exposure Time = *n* x 20 µs. So, for example, if the value stored in the SHUTTER register is 100 (0x064), the exposure time will be 100 x 20 µs or 2000 µs.

If you are operating the camera at a standard frame rate, you can determine the maximum shutter setting for that frame rate by reading the Max_Value field of the Shutter_Inq register (see page 4-6).

3.2.2 Maximum Exposure Time

The maximum exposure time for a given frame rate is determined by the following formula:

$$\frac{1}{\text{frame rate}} = \text{maximum exposure time}$$

For example, if a camera is operating at 40 fps:

$$\frac{1}{40\ \text{fps}} = 0.0250\ \text{s}$$

So in this case, the maximum exposure time is 25.0 ms.

ⓘ	Exceeding the maximum exposure time for your frame rate will cause the camera to slow down, i.e., it will cause the camera to operate at a lower frame rate.

3.2.3 Controlling Exposure Start with “Shot” Commands via the 1394 Interface

Exposure start can be controlled by sending “shot” commands directly to the camera via the 1394 bus. In this case, an external trigger (ExTrig) signal is not used. When exposure start is controlled via the 1394 bus, two modes of operation are available: one-shot and continuous-shot.

One-Shot Operation

In one-shot operation, the camera exposes and transmits a single image. Exposure begins after the One_Shot control register is set to 1 (see page 4-7). Exposure time is determined by the value field in the Shutter control register (see page 4-7).

The One_Shot control register is self cleared after transmission of the image data.

Continuous-Shot Operation

In continuous-shot operation, the camera continuously exposes and transmits images. The exposure of the first image begins after the Iso_En/Continuous_Shot control register is set to 1 (see page 4-7). The exposure time for each image is determined by the value field in the Shutter control register. The start of exposure on the second and subsequent images is automatically controlled by the camera.

If the camera is operating in video Format 0, the rate at which images will be captured and transmitted is determined by the value stored in the Cur_V_Frm_Rate / Revision control register (see page 4-7).

If the camera is operating in video Format 7, the rate at which images will be captured and transmitted is determined by the value stored in the Byte_Per_Packet control register (see pages 3-18 and page 4-10).

Image exposure and transmission stop after the Iso_En/Continuous_Shot control register is set to 0.

ⓘ	These explanations of exposure start are included to give the user a basic insight into the interactions of the camera’s registers. Typically, IEEE 1394 cameras are used with a driver which includes an interface that allows the user to parameterize and operate the camera without directly setting registers. The Basler BCAM 1394 Camera Driver, for example, has both a simple Windows® interface and a programmer’s API for parameterizing and operating the camera.

ⓘ	On **A601f-HDR** cameras, exposure of a new image can begin while the previous image is being read out. This is commonly referred to as “overlap mode.” Following the recommended method for exposure start in Section 3.2.5 will allow you to overlap exposure with readout and achieve the camera’s maximum frame rate.

3.2.4 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 or a falling edge of the signal can be used to trigger exposure start. The Trigger_Mode control register (see page 4-8) is used to enable ExTrig exposure start control and to select rising or falling edge triggering.

The ExTrig signal can be periodic or non-periodic. When the camera is operating under control of an ExTrig signal, the period of the ExTrig signal determines the camera's frame rate:

$$\frac{1}{\text{ExTrig period}} = \text{frame rate}$$

For example, if you are operating a camera with an ExTrig signal period of 20 ms:

$$\frac{1}{20\text{ ms}} = 50\text{ fps}$$

So in this case, the frame rate is 50 fps.

The minimum high time for a rising edge trigger signal (or low time for a falling edge trigger signal) is 1 µs.

Exposure Modes

If you are triggering the camera with an ExTrig signal, two exposure modes are available, programmable mode and level controlled mode.

Programmable Exposure Mode

When programmable mode is selected, the length of the exposure will be determined by the value stored in the Shutter control register (see page 4-7). If the camera is set for rising edge triggering, exposure starts when the ExTrig signal rises. If the camera is set for falling edge triggering, exposure starts when the ExTrig signal falls. Figure 3-3 illustrates programmable exposure with the camera set for rising edge triggering.

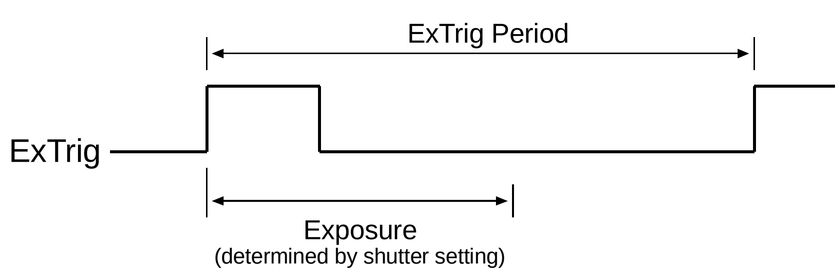

Figure 3-3: Programmable Exposure with Rising Edge Triggering

Level Controlled Exposure

When level controlled mode is selected, the length of the exposure will be determined by the ExTrig signal alone. If the camera is set for rising edge triggering, exposure begins when the ExTrig signal rises and continues until the ExTrig signal falls. If the camera is set for falling edge triggering, exposure begins when the ExTrig signal falls and continues until the ExTrig signal rises. Figure 3-4 illustrates level controlled exposure with the camera set for rising edge triggering.

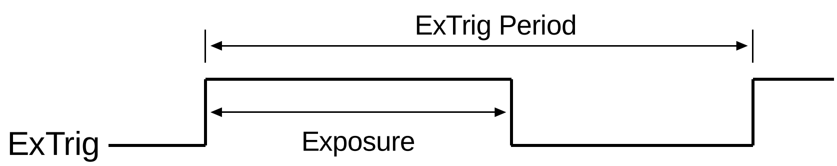

Figure 3-4: Level Controlled Exposure with Rising Edge Triggering

To enable the external trigger feature, set the On_Off field of the Trigger_Mode control register (see page 4-8) to 1.

To set the triggering for rising or falling edge, set the Trigger_Polarity field of the Trigger_Mode control register to 0 for falling edge or 1 for rising edge.

To set the exposure mode, set the Trigger_Mode field of the Trigger_Mode control register to 0 for the programmable exposure mode or 1 for the level controlled exposure mode.

The ExTrig signal must be used in combination with a one-shot or a 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 the Trigger Ready signal. (See Section 3.2.5 for recommended methods for using the signals)

The following descriptions assume that the ExTrig signal is set for rising edge triggering and the programmable exposure mode.

ExTrig/One-Shot Operation

In ExTrig/One-shot operation, a “One Shot Command” is used to prepare the camera to capture a single image. When the ExTrig signal rises, exposure will begin. 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. (See Section 3.3 for more about TrigRdy.)
4. When ExTrig rises, 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, readout and transmission of the captured image will take place.

The One_Shot control register is self cleared after frame transmission.

ExTrig/Continuous-Shot Operation

In ExTrig/Continuous-shot operation, a “Continuous Shot Command” is used to prepare the camera to capture multiple frames. In this mode, exposure will begin on each rising edge of the ExTrig signal. 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. (See Section 3.3 for more about TrigRdy.)
4. When ExTrig rises, 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, readout and transmission of the captured image will take place.
6. Repeat steps 3, 4, and 5 each time that you want to begin exposure and capture an image.
7. Image exposure and transmission stop when the Iso_En/Continuous_Shot control register is set to 0.

ⓘ	These explanations of exposure start are included to give the user a basic insight into the interactions of the camera’s registers. Typically, IEEE 1394 cameras are used with a driver which includes an interface that allows the user to parameterize and operate the camera without directly setting registers. The Basler BCAM 1394 Camera Driver, for example, has both a simple Windows® interface and a programmer’s API for parameterizing and operating the camera.

ⓘ	On **A601f-HDR** cameras, exposure of a new frame can begin while the previous frame is being read out. This is commonly referred to as “overlap mode.” Following the recommended method for exposure start in Section 3.2.5 will allow you to overlap exposure with readout and achieve the camera’s maximum frame rate.

3.2.5 Recommended Method for Controlling Exposure Start

ⓘ	The camera can be programmed to begin exposure on a rising edge or on a falling edge of an ExTrig signal. Also, two modes of exposure control are available: programmable and level controlled (see Section 3.2.4). For this illustration, we are assuming that a rising edge trigger and the programmable exposure mode are used.

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 (ExTrig) signal to start exposure.
- The user must monitor the trigger ready (TrgRdy) signal.
- A rising edge of the ExTrig signal must only occur when the TrgRdy signal is high.

Assuming that these general guidelines are followed, the reaction of the camera to a rising external trigger signal will be as shown in Figure 3-5:

- The start of exposure will typically occur 22 µs after the rise of the ExTrig signal.
- The integrate enabled (IntEn) signal will rise between 5 and 20 µs after the start of exposure.
- The actual length of exposure will be equal to the programmed exposure time.
- The IntEn signal will fall between 30 and 100 µs after the end of exposure.

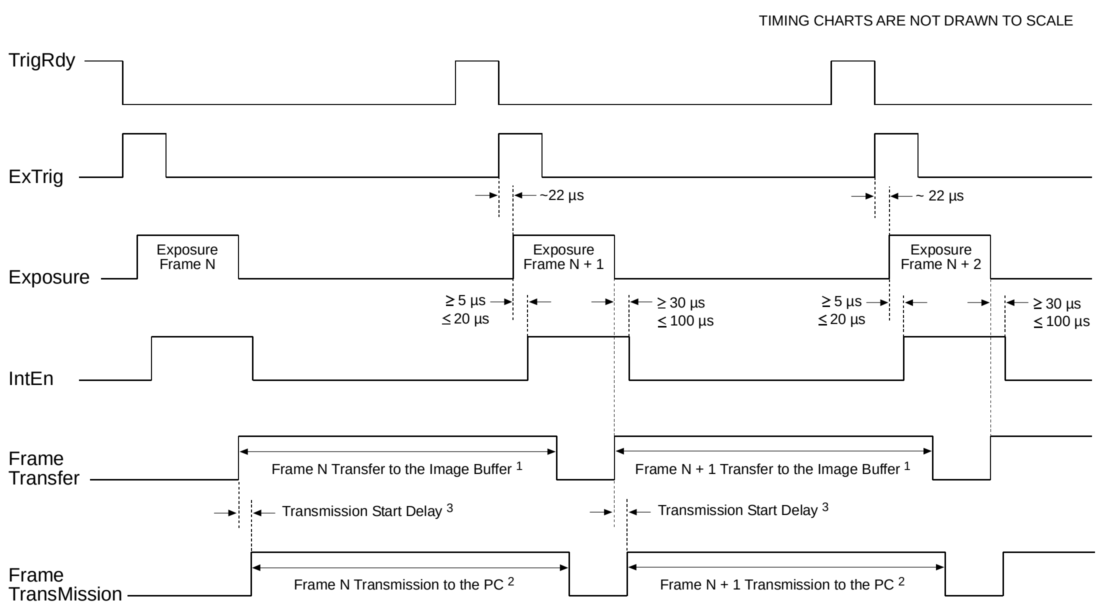

Figure 3-5: Exposure Start Controlled with an ExTrig Signal

[1] Frame Transfer Time = [(AOI Height + 2) x 15.28 µs] + 15.28 µs

[2] Frame Transmission Time = Packets/frame x 125 µs

[3] If the transmission time is greater than the transfer time:

Start Delay = 125 µs.

If the transmission time is less than the transfer time:

Start Delay = (Transfer Time - Transmission Time) + 125 µs

3.3 Trigger Ready Signal

ⓘ	The trigger ready signal is not defined in the 1394 Trade Association Digital Camera Specification. Trigger ready is a patented feature of Basler cameras that allows our cameras to have optimized timings.

The maximum frame rate for the camera can be limited by any one of three factors:

- The amount of time it takes to transfer a captured image from the CMOS sensor to the frame buffer.
- The amount of time it takes to transfer an image from the frame buffer to the PC via the IEEE 1394 bus.
- The exposure time setting.

The camera automatically recalculates the maximum frame rate any time a setting that effects one or more of these factors is changed. For example, the camera will recalculate the maximum frame rate if you change the exposure time, the size of the area of interest, or the packet size.

The camera will use the calculated maximum frame rate to generate a “trigger ready” (TrigRdy) signal. The trigger ready signal indicates the earliest moment that each exposure can begin without exceeding the maximum frame rate for the current conditions. The trigger ready signal will go low when each exposure is started and will go high when it is safe for the next exposure to begin (see Figure 3-5).

The TrigRdy signal is present on output 1 of the camera (see Section 2.4.2.2).

ⓘ	If you signal the camera to start an exposure when trigger ready is low, the camera will delay the start of exposure until the next rise of the trigger ready signal. This prevents you from running the camera faster than the maximum rate and avoids dropping frames. If the camera is in continuous shot mode and external triggering is disabled, the trigger ready output signal will not be present.

3.4 Integrate Enabled Signal

The Integrate Enabled (IntEn) signal goes high when exposure begins and goes low when exposure ends. 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. For example, assume that the camera is mounted on an arm mechanism and that the mechanism can 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 when exposure is taking place and thus know when to avoid moving the camera.

The IntEn signal is present on output 0 of the camera (see Section 2.4.2.1).

ⓘ	When you use the integrate enabled signal, be aware that there is a delay in the rise and the fall of the signal in relation to the start and the end of exposure. See Figure 3-5 for details.

3.5 Gain and Brightness

On **A601f-HDR** cameras, the output from the camera's sensor is digital and the gain and brightness functions are accomplished by manipulation of the sensor's digital output signal.

As shown in the top graph in Figure 3-6, when the gain is set to 0, the full 10 bit output range of the camera's CMOS sensor is mapped directly to the 8 bit output range of the camera. In this situation, a gray value of 0 is output from the camera when the pixels in the sensor are exposed to no light and a gray value of 255 is output when the pixels are exposed to very bright light. This condition is defined as 0 dB of system gain for the camera.

As shown in the three lower graphs, increasing the gain setting to a value greater than 0 maps a smaller portion of the sensor's 10 bit range to the camera's 8 bit output. When a smaller portion of the sensor's range is mapped to the camera's output, the camera's response to a change in light level is increased.

This can be useful when at your brightest exposure, a gray value of less than 255 is achieved. For example, if gray values no higher than 127 were achieved with bright light, you could increase the gain setting so that the camera is operating at 6 dB (an amplification factor of 2) and see an increase in gray values to 254.

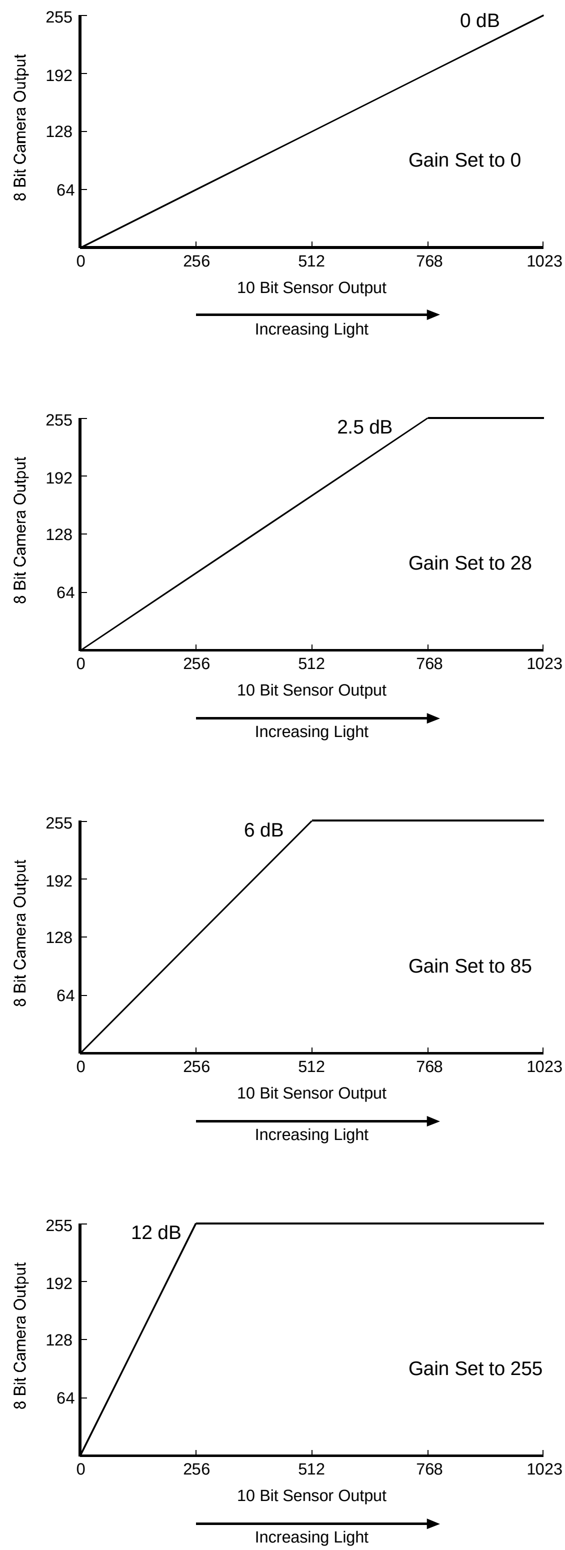

Figure 3-6: Mapping at Various Gain Settings

As shown in the top graph in Figure 3-7, setting the brightness higher than the default value of 725 moves the response curve to the left. This would increase the 8 bit value output from the camera for any given 10 bit value from the sensor and thus increase the apparent brightness of the image.

As shown in the bottom graph, setting the brightness lower than the default value of 725 moves the response curve to the right. This would decrease the 8 bit value output from the camera for any given 10 bit value from the sensor and thus decrease the apparent brightness of the image.

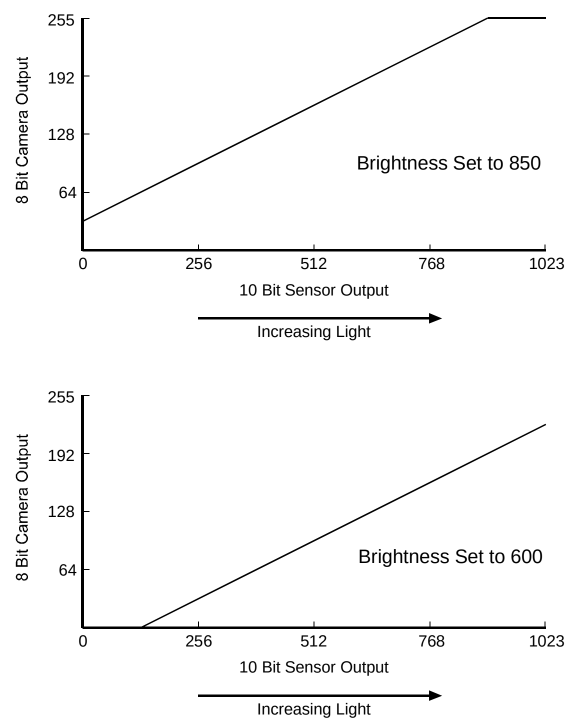

Figure 3-7: Brightness Setting Changes Mapping

3.5.1 Setting the Gain

The camera's gain setting is determined by the value field in the Gain control register (see page 4-8). The value can range from 0 to 255 (0x00 to 0xFF). Typical settings and the resulting amplification are shown in Table 3-1.

Decimal	Hex	dB	Amplification Factor
0	0x00	0.0	x 1.0
28	0x1C	2.5	x 1.3
43	0x2A	3.5	x 1.5
85	0x55	6.0	x 2.0

Decimal	Hex	dB	Amplification Factor
128	0x7F	8.0	x 2.5
170	0xAA	9.5	x 3.0
213	0xD4	10.9	x 3.5
255	0xFF	12.0	x 4.0

Table 3-1: Gain Settings

Because the sensor used on the **A601f-HDR** has a direct digital output, the implementation of the gain settings on **A601f-HDR** cameras is different from the implementation on other Basler cameras. This means that you can not directly compare the response of an **A601f-HDR** camera to another Basler camera with the same gain setting. For example, if you compare the response of an **A601f-HDR** with the gain set to 100 and an **A301f** with the same gain setting, you will see a significant difference. This happens because the gain scales on the two cameras are implemented differently and are not directly comparable.

3.5.2 Setting the Brightness

The camera's brightness is changed by setting the value field in the Brightness control register (see page 4-7). The setting can range on a decimal scale from 0 to 1023 (0x000 to 0x3FF). The default is typically 725 (0x2D5) by may vary slightly from camera to camera. Settings below the default decrease the brightness and settings above the default increase the brightness.

The effect of a change in the brightness setting varies depending on the gain setting. With the gain set to 0, changing the brightness setting by 4 results in a change of 1 in the digital values output by the camera. With the gain set to 255, changing the brightness setting by 1 results in a change of 1 in the digital values output by the camera.

3.6 Area of Interest (AOI)

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

The area of interest is referenced to the top left corner of the CMOS array. The top left corner is designated as column 0 and row 0 as shown in Figure 3-8.

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. 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 3-8.

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.

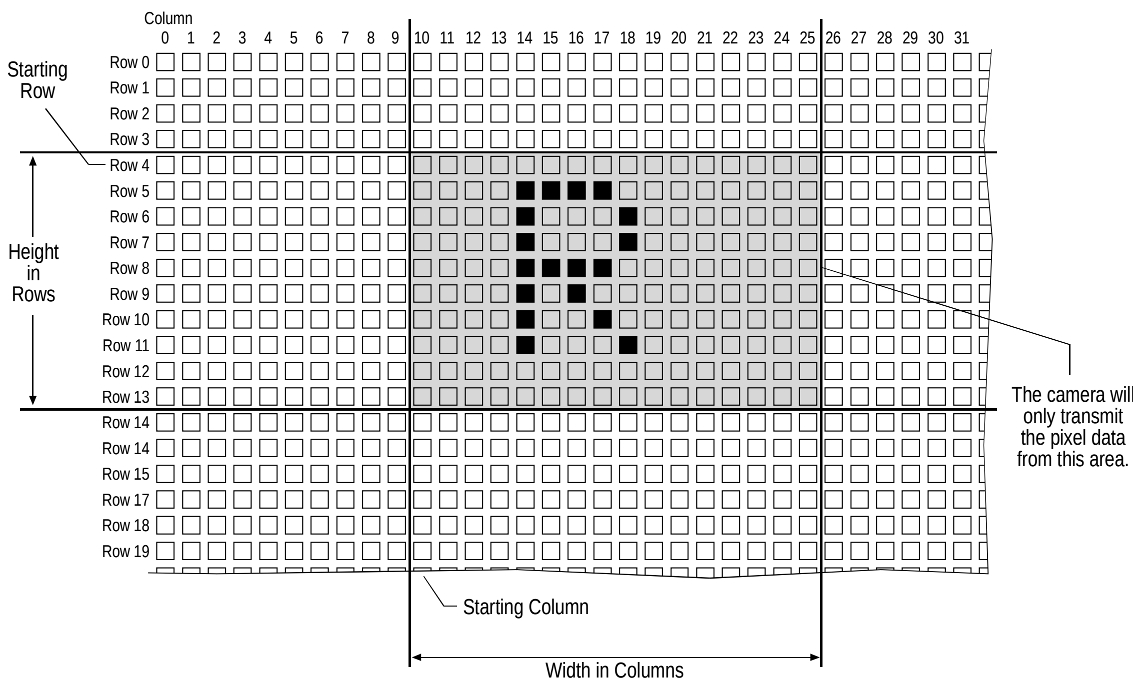

Figure 3-8: Area of Interest

The AOI feature is enabled by setting the camera to operate in Format_7, Mode_0. This is accomplished by setting the Cur_V_Format control register (see page 4-7) 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 for Format_7, Mode_0 (see page 4-9). 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 for Format_7, Mode_0.

To use the entire CMOS array in **A601f-HDR** cameras, set the value for "left" to 0, the value for "top" to 0, the value for "width" to 656 and the value for "height" to 491.

ⓘ	The sum of the setting for *Left* plus the setting for *Width* must not exceed 656. The sum of the setting for *Top* plus the setting for *Height* must not exceed 491 on monochrome cameras or 490 on color cameras.

3.6.1 Changing AOI Parameters "On-the-Fly"

Making AOI parameter changes "on-the-fly" means making the parameter changes while the camera is capturing images continuously. On-the-fly changes are only allowed for the parameters that determine the position of the AOI, i.e., the parameters for top and left. Changes to the AOI size are not allowed on-the-fly.

The camera's response to an on-the-fly change in the AOI position will vary depending on the way that you are operating the camera:

- If the exposure time is ≥ 100 µs, the changes will take effect on the next trigger after the changes are received by the camera.
- If the exposure time is < 100 µs and the camera is running in non-overlapped mode[1], the changes will take effect on the next trigger after the changes are received by the camera.
- If the exposure time is < 100 µs and the camera is running in overlapped mode[2], when the changes are received by the camera, the camera will delay the triggering of the next image until transmission of the current image is complete. When transmission of the current image is complete, the camera will change the AOI position, will trigger the next image, and will resume running in overlapped mode.

[1] The term "non-overlapped" mode means that image capture is triggered in the following manner: the camera captures (exposes) an image and completely transmits that image out of the camera before the next image capture is triggered. In other words, exposure and transmission of image N are both completed before exposure of image N+1 begins.

[2] The term "overlapped" mode means that image capture is triggered in the following manner: the camera captures (exposes) an image and while this image is being transmitted out of the camera, capture of the next image is triggered. In other words, capture of image N+1 begins while transmission of image N is still in progress.

3.7 Selectable 8 or 10 Bit Pixel Depth

When an **A601f-HDR** camera is operating in Format 7 Mode 0, it can be set to output pixel data at either 8 bit or 10 bit depth.

For 8 Bit Depth

Set the Color_Coding_ID field of the Format_7, Mode_0 register for Mono 8 (see page 3-18). With this ID set, the camera outputs 8 bits per pixel.

For 10 Bit Depth

Set the Color_Coding_ID field of the Format_7, Mode_0 register for Mono 16. With this ID set, the camera outputs 16 bits per pixel but only 10 bits are effective. The effective pixel data fills from the LSB and the unused bits are filled with zeros. Pixel data is stored in the PC memory in little endian format, i.e., the low byte for each pixel is stored at the lower address and the high byte is stored at the neighboring higher address.

On an **A601f-HDR** set to Mono 16, the maximum frame rate is 30 fps.

3.8 Available Video Formats, Modes, and Frame Rates

3.8.1 Standard Formats, Modes, and Frame Rates

The following standard video formats, modes, and frame rates are available on the **A601f-HDR**:

Format_0, Mode_5, FrameRate_0 (Mono, 8 bits/pixel, 640 x 480 pixels at 1.875 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_0, Mode_5, FrameRate_4 (Mono, 8 bits/pixel, 640 x 480 pixels at 30 fps)

Format_0, Mode_5, FrameRate_5 (Mono, 8 bits/pixel, 640 x 480 pixels at 60 fps)

Format_0, Mode_1, FrameRate_0 (YUV 4:2:2, 16 bits/pixel avg., 320 x 240 pixels at 1.875 fps)

Format_0, Mode_1, FrameRate_1 (YUV 4:2:2, 16 bits/pixel avg., 320 x 240 pixels at 3.75 fps)

Format_0, Mode_1, FrameRate_2 (YUV 4:2:2, 16 bits/pixel avg., 320 x 240 pixels at 7.5 fps)

Format_0, Mode_1, FrameRate_3 (YUV 4:2:2, 16 bits/pixel avg., 320 x 240 pixels at 15 fps)

Format_0, Mode_1, FrameRate_4 (YUV 4:2:2, 16 bits/pixel avg., 320 x 240 pixels at 30 fps)

ⓘ	YUV 4:2:2 output is normally associated with color cameras, but **A601f-HDR** cameras are monochrome. When an **A601f-HDR** camera is set for YUV 4:2:2, its output will be in the YUV 4:2:2 format but the output will be monochrome, not color. This monochrome version of the YUV 4:2:2 format is provided so that the camera can be used with Windows XP accessories such as Movie Maker.

3.8.2 Customizable Formats and Modes

Format_7, Mode_0 and Format_7, Mode_2 are available on the **A601f-HDR**.

Format_7, Mode_0

Format_7, Mode_0 is available on **A601f-HDR** cameras. This mode is used to enable and set up the area of interest (AOI) feature described in Section 3.6. Format_7, Mode 0 is parameterized by using the Format_7, Mode 0 control and status registers (see page 4-9).

When the camera is operating in Format_7, Mode_0, the frame rate can be adjusted by setting the number of bytes transmitted in each packet. The number of bytes per packet is set by the BytePerPacket field of the Byte_Per_Packet register.

The value that appears in the MaxBytePerPacket field of the Packet_Para_Inq control register will show the maximum allowed bytes per packet setting given the current AOI settings. When the bytes per packet is set to the maximum, the camera will transmit frames at its maximum specified rate. By default, the AOI is set to use the full sensor area and the bytes per packet is set to 4092.

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

$$\text{Frames/s} = \frac{1}{\text{Packets per Frame x 125 µs}}$$

Keep in mind that when you lower the bytes per packet setting, the number of bytes needed to transmit a frame (the packets per frame) will increase. Due to limitations in the DCAM structure, a maximum of 4095 packets per frame is allowed. If you set the bytes per packet too low, the number of packets per frame will exceed the 4095 packet limit and the camera will not transmit frames properly.

ⓘ	When the camera is operating in Format_7, the Cur_V_Frame_Rate control register is not used and has no effect on camera operation.

Color Codings

In Format_7, Mode_0, the Mono 8 and Mono 16 color codings are available:

When the **Mono 8** ID is set in the Color_Coding_ID field of the Format_7, Mode_0 register, the camera outputs 8 bits per pixel.

When the **Mono 16** ID is set in the Color_Coding_ID field of the Format_7, Mode_0 register, the camera outputs 16 bits per pixel but only 10 bits are effective. The effective pixel data fills from the LSB and the unused bits are filled with zeros. Pixel data is stored in the PC memory in little endian format, i.e., the low byte for each pixel is stored at the lower address and the high byte is stored at the neighboring higher address.

When the camera is set for Mono 16 the maximum frame rate is 30 fps.

ⓘ	Color code definitions can vary from camera model to camera model. This is especially true for older models of Basler cameras.

Format_7, Mode_2

Format_7, Mode_2 is available on **A601f-HDR** cameras. This mode must be used when the High Dynamic Range smart feature is enabled as described in Section 6. Format_7, Mode 2 is parameterized by using the Format_7, Mode 2 control and status registers (see page 4-11).

The frame rate can be adjusted by setting the control and status registers for Format_7, Mode_2 in the same manner as described for Format_7, Mode_0.

Color Codes

In Format_7, Mode_2, the Mono 8, Mono 16, and Vendor Specific 0 color codings are available.

When the **Mono 8** ID is set in the Color_Coding_ID field of the Format_7, Mode_2 register, the camera outputs 8 bits per pixel. Each 8 bit value directly represents the value of a pixel.

When the **Mono 16** ID is set in the Color_Coding_ID field of the Format_7, Mode_2 register, the camera outputs 16 bits per pixel. Pixel data is stored in the PC memory in little endian format, i.e., the low byte for each pixel is stored at the lower address and the high byte is stored at the neighboring higher address. Each 16 bit value directly represents the value of a pixel.

When the **Vendor Specific 0** ID is set in the Color_Coding_ID field of the Format_7, Mode_2 register, the camera outputs 16 bits per pixel. Pixel data is stored in the PC memory in little endian format, i.e., the low byte for each pixel is stored at the lower address and the high byte is stored at the neighboring higher address. With the Vendor Specific 0 color coding, each 16 bit value does not directly represent the value of a pixel. The 16 bits represent a coding which must be properly interpreted to obtain the actual pixel value.

With the Vendor Specific 0 coding, the least significant byte of the 16 bits represents a base (unsigned) and the most significant byte represents an exponent. The actual value of the pixel is:

$$\text{Actual Pixel Value} = \text{Base} \times 2^{\text{exponent}}$$

For example, if an **A601f-HDR** camera was set for Vendor Specific 0 color coding and it transmitted a value of 0x0220, the base would be 32 (decimal) and the exponent would be 2 (decimal). The actual pixel value would be:

$$\text{Actual Pixel Value} = 32 \times 2^{2}$$

$$\text{Actual Pixel Value} = 128$$

See Section 6.3.2 for more information about the color codings used with Format_7, Mode_2.

ⓘ	The Vendor Specific 0 color coding is defined in version 1.31 of the IIDC specification. Color code definitions can vary from camera model to camera model. This is especially true for older models of Basler cameras.

4 Configuring the Camera

The **A601f-HDR** is configured by setting status and control registers as described in 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.) Except where noted, all registers conform to version 1.30 of the specification.

If you are creating your own driver to operate the camera, Sections 4.1 through 4.5 provide the basic information 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 **A601f-HDR**. The Basler BCAM 1394 Driver/Software Development Kit 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/SDK comes 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 and block writes. If you do a single read or a block read, the camera will return a 0 for all non-existent registers. If you do a single write to a non-existent register or a block write that includes non-existent registers, the writes to non-existent registers will have no effect on camera operation.

4.2 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 from Format 7 to Format 0, you must also write the Cur_V_Mode and the Cur_V_Frm_Rate.

If the Cur_V_Format is changed from Format 0 to Format 7, you must also write the Cur_V_Mode, the Image_Position, the Image_Size and the Bytes_Per_Packet. (See Section 3.8.2 for more information on setting the Bytes per Packet in Format 7).

4.3 Configuration ROM

The configuration ROM in the **A601f-HDR** is compliant with the DCAM specification V 1.30

4.4 Implemented Standard Registers

A list of all standard registers implemented in **A601f-HDR** 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.

4.4.1 Inquiry Registers

Camera Initialize Register

Offset	Name	Notes
000h	Initialize	Camera will reset itself, break any state lock, and re-initialize itself to factory settings.

Inquiry Register for Video Format

Offset	Name	Notes
100h	V_Format_Inq	The A601f-HDR supports format_0 and format_7.

Inquiry Registers for Video Mode

Offset	Name	Notes
180h	V_Mode_Inq_0 (Format 0)	In format_0, the A601f-HDR supports: • mode_1 (320 x 240, pseudo YUV 4:2:2*, 16 bits/pix. avg.) • mode_5 (640 x 480, mono, 8 bits/pixel)
19Ch	V_Mode_Inq_7 (Format 7)	In format_7, the A601f-HDR supports: • mode_0 (656 x 491) • mode_2 (656 x 491)

* See Section 3.8.1 for more information on the pseudo YUV 4:2:2 mode

Inquiry Registers for Video Frame Rate

Offset	Name	Notes
204h	V_Rate_Inq_0_1 (Format_0, Mode_1)	In format 0, mode 1, the A601f-HDR supports the following frame rates: • 1.875 fps (frame rate 0) • 3.75 fps (frame rate 1) • 7.5 fps (frame rate 2) • 15 fps (frame rate 3) • 30 fps (frame rate 4)
214h	V_Rate_Inq_0_5 (Format_0, Mode_5)	In format 0, mode 5, the A601f-HDR supports the following frame rates: • 1.875 fps (frame rate 0) • 3.75 fps (frame rate 1) • 7.5 fps (frame rate 2) • 15 fps (frame rate 3) • 30 fps (frame rate 4) • 60 fps (frame rate 5)

CSR Inquiry Registers for Format 7

Offset	Name	Notes
2E0h	V_CSR_Inq_7_0	The A601f-HDR implements the CSR for format_7, mode_0.
2E8h	V_CSR_Inq_7_2	The A601f-HDR implements the CSR for format_7, mode_2.

Inquiry Register for Basic Functions

Offset	Name	Notes
400h	Basic_Func_Inq	The A601f-HDR supports the following basic functions: • Advanced_Feature_Inq • Vmode_Error_Status_Inq • Feature_Control_Error_Status • One_Shot_Inq

Inquiry Registers for Feature Presence

Offset	Name	Notes
404h	Feature_Hi_Inq	The A601f-HDR supports the following features: • Brightness • Shutter • Gain • Trigger
408h	Feature_Lo_Inq	= 0
480h	Advanced_Feature_Inq	The A601f-HDR implements a Basler advanced feature set.

Inquiry Registers for Feature Elements

Offset	Name	Notes
500h	Brightness_Inq	The A601f-HDR supports the following sub-features for brightness: • Presence_Inq • ReadOut_Inq • Manual_Inq • Min_Value = 0x000 • Max_Value = 0x3FF
51Ch	Shutter_Inq	The A601f-HDR supports the following sub-features for shutter: • Presence_Inq • ReadOut_Inq • Manual_Inq • Min_Value = 0x001 • Max_Value = depends on format and mode For format 0, the max shutter setting depends on the frame rate: at 1.875 fps, max = 4095 (0xFFF) at 3.75 fps, max = 4095 (0xFFF) at 7.5 fps, max = 4095 (0xFFF) at 15 fps, max = 3331 (0xD03) at 30 fps, max = 1665 (0x681) at 60 fps, max = 831 (0x33F) For format 7, the max shutter setting is 0xFFF
520h	Gain_Inq	The A601f-HDR supports the following sub-features for gain: • Presence_Inq • ReadOut_Inq • Manual_Inq • Min_Value = 0x000 • Max_Value = 0x0FF
530h	Trigger_Inq	The A601f-HDR supports the following sub-features for trigger: • Presence_Inq • ReadOut_Inq • OnOff_Inq • Polarity_Inq • Trigger_Mode0_Inq • Trigger_Mode1_Inq

4.4.2 Control and Status Registers

Status and Control Registers for the Camera

Offset	Name	Notes
600h	Cur_V_Frame_Rate	Default = 0
604h	Cur_V_Mode	Default = 0
608h	Cur_V_Format	Default = Format 7
60Ch	Iso_Channel / Iso_Speed	Default Channel =0 Default Speed = S400
614h	Iso_En Continuous Shot	Default = 0
61Ch	One_Shot / Multi_Shot	Default = 0 Multi_Shot is not supported
630h*	Data_Depth	Default = 8 Read only

* This register is defined in version 1.31 of the IIDC specification.

Status and Control Registers for Features

Offset	Name	Notes
800h	Brightness	Brightness settings range from 0 to 1023 (0x000 to 0x3FF). Typical default = 725 (0x2D5). Settings below the default decrease the brightness and settings above the default increase the brightness. The effect of a change in the brightness setting varies depending on the gain setting. With the gain set to 0, changing the brightness setting by 4 results in a change of 1 in the digital values output by the camera. With the gain set to 255, changing the brightness setting by 1 results in a change of 1 in the digital values output by the camera.
81Ch	Shutter	Shutter settings range from 1 (0x001) to 4095 (0xFFF). Exposure time = (shutter register value) x 20 µs Default = 498 (0x1F2) = 9.96 ms

Offset	Name	Notes
820h	Gain	Gain settings range from 0 (0x00) to 255 (0xFF). A setting of 0x00 results in a gain of 1x (0dB) A setting of 0xFF results in a gain of 4x (12 db) Default = 28 (0x1C) resulting in a gain of 2.5 dB
830h	Trigger_Mode	Setting On_Off to: 0 = disable trigger use {=default} 1 = enable trigger use Setting Trigger_Polarity to: 0 = low active 1 = high active {= default} Setting Trigger_Mode to: 0 = mode 0 (programmable mode) 1 = mode 1 (level mode) The parameter portion of the register is ignored.

Control and Status Registers for Format_7, Mode_0

Format_7, Mode_0 is available on **A601f-HDR** cameras.The base address for each Format_7, Mode_0 camera control register is:

Bus_ID, Node_ID, FFFF F1F0 0000

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

Offset	Name	Notes
000h	Max_Image_Size_Inq	Hmax = 656 Vmax = 491 The VGA sub-image is positioned in the center of the full size image.
004h	Unit_Size_Inq	Hunit = 1 Vunit = 1
008h	Image_Position	Default = (0, 0)
00Ch	Image_Size	Default = (Hmax, Vmax)
010h	Color_Coding_ID	Default = Mono 8 (ID = 0)
014h	Color_Coding_Inq	The A601f-HDR supports the following color codes in this mode: • Mono 8 (ID = 0) • Mono16 (ID = 5)
024h*	Color_Coding_Inq	Field is not used in this mode.
034h	Pixel_Number_Inq	The value of this register depends on the following registers: • Image_Size
038h	Total_Bytes_Hi_Inq	The value of this register depends on the following registers: • Image_Size • Color_Coding_ID The value Includes the following data: • Image data • Padding bytes • Data added by any enabled smart features
03Ch	Total_Bytes_Lo_Inq	See Total_Bytes_Hi_Inq register
040h	Packet_Para_Inq	UnitBytePerPacket = 4 MaxBytePerPacket depends on: • Image_Size • Color_Coding_ID

* This field is defined in version 1.31 of the IIDC specification.

<table>
<tr><th>Offset</th><th>Name</th><th>Notes</th></tr>
<tr><td>044h</td><td>Byte_Per_Packet</td><td>BytePerPacket = set by user *
RecBytePerPacket = 4092 (0xFFC)</td></tr>
<tr><td>048h</td><td>Packet_Per_Frame_Inq</td><td>The value of this register depends on the following registers:
• Image_Size
• Color_Coding_ID
• Byte_Per_Packet
The value Includes the following data:
• Image data
• Padding bytes
• Data added by any enabled smart features</td></tr>
<tr><td>04Ch</td><td>Unit_Position_Inq</td><td>Hposunit = 1, Vposunit = 1</td></tr>
<tr><td>054h **</td><td>Data_Depth</td><td>Indicates the effective data depth of the pixel information being transmitted from the camera.
The value of this register depends on the following registers:
• Color_Coding_ID
In Format _7, Mode_0:
Color_Coding_ID | Effective Data Depth | Bits Transmitted
ID = 0 (Mono 8) | 8 | 8
ID = 5 (Mono 16) | 10 | 16
ID = 2 (YUV 4:2:2) | 8 | 16</td></tr>
</table>

* When you lower the bytes per packet setting, the number of bytes needed to transmit a frame (the packets per frame) will increase. Due to limitations in the DCAM structure, a maximum of 4095 packets per frame is allowed. If you set the bytes per packet too low, the number of packets per frame will exceed the 4095 packet limit and the camera will not transmit frames properly.

** This field is defined in version 1.31 of the IIDC specification.

Control and Status Registers for Format_7, Mode_2

Format_7, Mode_2 is available on **A601f-HDR** cameras.The base address for each Format_7, Mode_2 camera control register is:

Bus_ID, Node_ID, FFFF F1F0 0200

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

Offset	Name	Notes
000h	Max_Image_Size_Inq	Hmax = 656 Vmax = 491 The VGA sub-image is positioned in the center of the full size image.
004h	Unit_Size_Inq	Hunit = 1 Vunit = 1
008h	Image_Position	Default = (0, 0)
00Ch	Image_Size	Default = (Hmax, Vmax)
010h	Color_Coding_ID	Default = Mono 8 (ID = 0)
014h	Color_Coding_Inq	The A601f - HDR supports the following color codes in this mode: • Mono 8 (ID = 0) • Mono 16 (ID = 5)
024h *	Color_Coding_Inq	• Vendor Specific 0 (ID = 128) **
034h	Pixel_Number_Inq	The value of this register depends on the following registers: • Image_Size
038h	Total_Bytes_Hi_Inq	The value of this register depends on the following registers: • Image_Size • Color_Coding_ID The value includes the following data: • Image data • Padding bytes • Data added by any enabled smart features
03Ch	Total_Bytes_Lo_Inq	See Total_Bytes_Hi_Inq register

* This field is defined in version 1.31 of the IIDC camera specification.

** The Vendor Specific 0 color coding is unique to Basler. When this color coding is selected, the camera outputs 16 bits per pixel but the 16 bits do not directly represent a pixel value. See page 3-19 and Section 6.3.2 for more information.

Offset	Name	Notes
040h	Packet_Para_Inq	UnitBytePerPacket = 4 MaxBytePerPacket depends on: • Image_Size • Color_Coding_ID
044h	Byte_Per_Packet	BytePerPacket = set by user RecBytePerPacket = 4092 (0xFFC)
048h	Packet_Per_Frame_Inq	The value of this register depends on the following registers: • Image_Size • Color_Coding_ID • Byte_Per_Packet The value includes the following data: • Image data • Padding bytes • Data added by any enabled smart features
04Ch	Unit_Position_Inq	Hposunit = 1 Vposunit = 1
054h*	Data_Depth	Indicates the effective data depth of the pixel information being transmitted from the camera. The value of this register depends on the following registers: • Color_Coding_ID In Format _7, Mode_2: *Color_Coding_ID* / *Effective Data Depth* / *Bits Transmitted* ID = 0 (Mono 8) 8 8 ID = 5 (Mono 16) 16 16 ID = 128 (Vend Spec 0) ** 16 16

* This field is defined in version 1.31 of the IIDC specification.

** The Vendor Specific 0 color coding is unique to Basler. When this color coding is selected, the camera outputs 16 bits per pixel but the 16 bits do not directly represent a pixel value. See page 3-19 and Section 6.3.2 for more information.

4.5 Advanced Features Registers

ⓘ	The functionally of the advanced features control and status registers has been made part of Basler's Smart Features Framework (SFF). We strongly recommend that you use the SFF registers (see Section 5) rather than the advanced features registers. To ensure backward compatibility, the existing advanced features registers described below will continue to be supported, but their functionality will not be extended in the future.

The base address for the advanced features registers 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.

4.5.1 Advanced Features Access Control Register

Advanced Features Access Control Register

Offset	Name	Notes
0000h	ACCESS_CONTROL_REGISTER	See DCAM Spec. V1.30 page 26.

4.5.2 Advanced Features Inquiry Registers

Inquiry Register for Advanced Features (High)

Offset	Name	Field	Bit	Description
0008h	ADV_INQ_HI	Presence	[0]	Presence of this feature
		Test Image	[1]	Presence of test images
		Shading	[2]	Presence of shading correction
		---	[3]	Reserved
		Extd. Versions	[4]	Presence of extended versions
		Firmware Upload	[5]	Presence of firmware upload capability
		---	[6..31]	Reserved

Inquiry Register for Advanced Features (Low)

Offset	Name	Field	Bit	Description
000Ch	ADV_INQ_LO	Presence	[0]	Presence of this feature
		---	[1..31]	Reserved

Inquiry Register for Extended Version Information

Offset	Name	Field	Bit	Description
1010h	EXTD_VERSIONS_INQ	Presence	[0]	Presence of this feature
		---	[1..7]	Reserved
		Length	[8..15]	Specifies the length in quadlets of the "String" field in the Extended Versions Information Register (see below).
		---	[16..31]	

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 Extended Version Information (see above).
This string contains the camera's "firmware ID" number. You can read the string to determine your camera's firmware ID. The ID number's position in the string is described in Section 1.1. For troubleshooting purposes, Basler technical support may ask you to read this register and to supply the results.				

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 5.7.6 for a description of the available test images).

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 Smart Features and the Smart Features Framework

5.1 What are Smart Features

Smart features are features unique to Basler cameras. Test Images, the Cycle Time Stamp, and the CRC (Cyclic Redundancy Check) Checksum are examples of Basler smart features.

In some cases, enabling a smart feature will simply change the behavior of the camera. The Test Image feature is a good example of this type of smart feature. When the Test Image feature is enabled, the camera outputs a test image rather than a captured image.

When certain smart features are enabled, the camera actually develops some sort of information about each image that it acquires. In these cases, the information is added to each image as trailing data when the image is transmitted from the camera. Examples of this type of smart feature are the Cycle Time Stamp feature and the CRC Checksum. When the Cycle Time Stamp feature is enabled, after an image is captured, the camera determines when the acquisition occurred and develops a cycle time stamp for the image. And if the CRC Checksum feature is enabled, the camera calculates a checksum for the image. The cycle time stamp and checksum are added as trailing data to each image as the image is transmitted from the camera.

5.2 What is the Smart Features Framework

The first component of the Smart Features Framework (SFF) is a mechanism that allows you to enable and to parametrize smart features. This mechanism is essentially an extension of the register structure defined in the DCAM specification for use with “Advanced Features.” The SFF establishes a register for each smart feature. By setting bits within the register for a particular smart feature, you can enable the feature and control how the feature operates.

When certain smart features are enabled, the camera actually develops some sort of data about each image that it acquires. For example, when the Cycle Time Stamp feature is enabled, the camera creates a time stamp for each image based on when the image exposure started. In the cases where a smart feature develops some sort of data about a captured image, the smart feature’s data is added as trailing data to each image as the image is transmitted from the camera.

The SFF provides a mechanism for parsing the smart features data added to images transmitted out of the camera by assigning a unique identifier (GUID) to each smart feature. Whenever the camera adds data for a smart feature to an image, it includes the GUID for the smart feature as part of the added data. The GUIDs are especially useful when you enable several smart features that add data to the image stream. The GUIDs make it possible to identify which portion of the added data is the result of each enabled smart feature. Refer to Sections 5.6 and 5.7 for detailed information about getting smart features results.

5.3 What do I Need to Use Smart Features

To use smart features you will need:

- A camera that supports smart features. Not all camera models support smart features. And with some camera models that do support smart features, you may find that older cameras may not support all available smart features or may not support smart features at all. Section 5.5 contains information about checking a camera to see if it supports smart features.
- A method of accessing the camera's DCAM register structure. We strongly recommend that you use the Basler BCAM 1394 Driver (v1.7 or higher) along with the Basler Smart Features Framework software to access the registers. (See Section 5.4 for more information about the SFF Software.)

ⓘ	We strongly recommend that you use the Basler BCAM 1394 driver. However, any driver that can get images in format 7 and that provides access to the DCAM registers can be used to work with smart features. If you do use a different driver, you can adapt the access techniques described in the SFF Software tutorial (see Section 5.4) to the driver you are using. You should be aware that drivers other than the Basler BCAM driver have not been tested with smart features.

5.4 What is the Smart Features Framework Software?

A Smart Features Framework Software (SFF Software) package is available from Basler. The SFF Software has two major components:

- An SFF Viewer. The viewer is a Windows® based tool that allows you to easily enable and disable smart features, parameterize the camera, capture and view images, and view smart features results.
- An SFF Tutorial. The tutorial explains how to access the cameras smart features from within your own applications. The tutorial is based on the assumption that you are using the Basler BCAM 1394 driver with your camera.

The SFF software package is available for download at the Basler web site. To download the software, go to:

http://www.baslerweb.com/popups/popup_en_1825.php

ⓘ	The SFF Viewer will only work on PCs that have the BCAM driver v1.7 or higher installed.

5.5 Enabling and Parameterizing Smart Features

The camera provides a control and status register (CSR) for each smart feature (see Sect 5.7 for details of each feature and its CSR). To enable and parameterize a smart feature, the following steps must be performed:

1. Check to see if the camera supports smart features.
2. Ask the camera for the address of the CSR for the desired smart feature.
3. Enable and parameterize the desired smart features.

The next two sections describe steps 1 and 2. The layout of the registers used to enable and parameterize the smart features is described in section 5.7.

5.5.1 Checking to see if the Camera Supports Smart Features

Smart features are vendor unique. Such features are referred to in the 1394 Trade Association DCAM standard as advanced features. The DCAM standard specifies how vendors should implement advanced features. According to the standard, advanced features must be unlocked (that is, enabled) by writing an advanced features set identifier (Feature ID) and a time-out value to the Advanced Features Access Control Register. From the point of view of the DCAM standard, smart features are a set of advanced DCAM features. The Feature ID associated with Basler smart features is 0x0030 533B 73C3.

For Basler cameras, unlocking advanced features is not strictly necessary because any implemented smart features are always available. However, the unlock mechanism is also used to check to see if a camera supports vendor unique features such as smart features. If a device doesn't recognize a Feature ID written to the Access Control Register, a value of 0xFFFF FFFF FFFF FFFF will be read back from the ACR. This value indicates that the device does not implement the feature set associated with that Feature ID.

Assuming that the address of the Advanced Features Access Control Register is 0xFFFF F2F0 0000, perform the following steps to see if a camera is smart features capable:

1. Write the quadlet data 0x0030 533B to 0xFFFF F2F0 0000
2. Write quadlet data 0x73C3 F000* to 0xFFFF F2F0 0004
3. Read quadlet data from 0xFFFF F2F0 0000 and 0xFFFF F2F0 0004. If at least one of the read operations returns a value that is not equal to 0xFFFF FFFF, the camera supports smart features. If both read operations return 0xFFFF FFFF, the camera does not support smart features.

Note that instead of performing two single quadlet write operations, a block write can be performed.

* The last three zeros in this quadlet data represent a timeout value. See page 26 in version 1.30 of the “1394-Based Digital Camera Specification”

5.5.2 Determining the Address a Smart Feature's CSR

The control and status register (CSR) for each smart feature is identified by a 128 bit Globally Unique Identifier (GUID). GUIDs are also known as UUIDs (Universal Unique Identifier).

A GUID consists of:

- One 32 bit number (D1)
- Two 16 bit numbers (D2, D3)
- A sequence of 8 bytes (D4[0] - D4[7])

GUID example:

CA8A916A	-	14A4	-	4D8E	-	BBC9	-	93DF50495C16
(D1)		(D2)		(D3)		(D4[0] - D4[1])		(D4[2] - D4[7])

Section 5.7 describes the standard smart features available on **A601f-HDR** cameras. Each smart feature description includes the GUID assigned to the feature's CSR.

To determine the starting address of a smart feature's CSR, the feature's CSR GUID must be written to the Smart Features Inquiry register (SF_Inq_Register). The SF_Inq_Register's offset relative to the Access Control Register is 0x10. If the camera recognizes the GUID as the CSR GUID for an implemented smart feature, the address of CSR for the feature can be read from the Smart Features Address Register (SF_Addr_Register) at offset 0x20. If the feature isn't supported by the device, a value of 0x0 will be read from the SF_Addr_Register.

SF_Inq_Register Layout

	Bit			
Offset	0-7	8-15	16-23	24-31
10h	D1			
14h	D3		D2	
18h	D4[3]	D4[2]	D4[1]	D4[0]
1ch	D4[7]	D4[6]	D4[5]	D4[4]

SF_Addr_Register Layout

	Bit			
Offset	0-7	8-15	16-23	24-31
20h	Address_Lo			
24h	Address_Hi			

Example

Determine the address of the “CRC Checksum” smart feature which has a CSR GUID of:

3B34004E - 1B84 - 11D8 - 83B3 - 00105A5BAE55

D1: 0x3B34 004E

D2: 0x1B84

D3: 0x11D8

D4[0]: 0x83

D4[1]: 0xB3

D4[2]: 0x00

D4[3]: 0x10

D4[4]: 0x5A

D4[5]: 0x5B

D4[6]: 0xAE

D4[7]: 0x55

Step 1: Write the CSR GUID to the SF_Inq_Register

Assuming that the address for the ACR is 0xFFFF F2F0 0000, perform the following quadlet write operations to the SF_Inq_Register

a. Write quadlet data 0x3B34 004E to 0xFFFF F2F0 0010 (D1)

b. Write quadlet data 0x11D8 1B84 to 0xFFFF F2F0 0014 (D3 | D2)

c. Write quadlet data 0x1000 B383 to 0xFFFF F2F0 0018 (D4[3] | D[0])

d. Write quadlet data 0x55AE 5B5A to 0xFFFF F2F0 001C (D4[7] | D[4])

Instead of performing four quadlet write operations, one block write operation can be performed.

Step 2: Read the start address for the smart feature from the SF_Addr_register

a. Read quadlet data from 0xFFFF F2F0 0020 (Address_Lo)

b. Read quadlet data from 0xFFFF F2F0 0024 (Address_Hi)

If both Address_Lo and Address_Hi return zero, the camera doesn’t support the CRC checksum feature. Assuming the read operations yielded Address_Lo = 0xF2F0 0038 and Address_Hi = 0x0000 FFFF, the CRC Checksum feature CSR’s address is 0xFFFF F2F0 0038.

5.5.3 Enabling and Parameterizing a Smart Feature

Once you have determined the starting address of the control and status register (CSR) for your desired smart feature, you are ready to enable and parameterize the feature by setting bits within the CSR.

Section 5.7 describes the standard smart features available on **A601f-HDR** cameras. Each smart features description includes an explanation of what the feature does and an explanation of the parameters associated with the feature. The descriptions also include a detailed layout of how the bits contained within the feature's CSR relate to the parameters for the feature. After reading the description of your desired smart feature, you can enable and parameterize the feature by setting the appropriate bits within the CSR.

5.6 Getting Smart Features Results

In many cases, activating a smart feature results in additional data that must be transmitted by the camera, i.e., the results of the smart feature. The results of a smart feature will be appended to the image data so that each frame contains both image data and smart features results.

Before using any of the smart features that add information to the image data, the extended data stream feature must be enabled. The extended data stream is in itself a smart feature. When the extended data stream feature is enabled, information such as the height of the image, the width of the image, and the AOI size is added to each image's basic pixel data. Disabling the extended data stream feature switches off all smart features that add information to the image data stream.

The extended data stream feature and any other smart features which add information to the image data stream will only work when the camera is set for video format 7. For other video formats, enabling the extended data stream feature or any of the other smart features that normally add data to the image stream does not affect the image data stream; the camera only sends the basic image data without any added information.

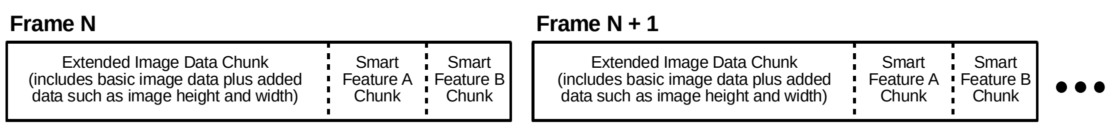

Figure 5-1: Image Data Stream with Smart Features Enabled

As illustrated in Figure 5-1, when smart features are enabled, each image frame consists of "chunks." For example, the frame may include a chunk which contains the extended image data (the basic image data plus the added height, width, etc. information), a chunk which contains the results for the frame counter smart feature, a chunk which contains the results for the cycle time stamp smart feature, etc. Table 5-1 describes the general structure of a chunk.

Position	Name	Description
0	Data [K Bytes]	The data that the chunk is transporting.
K	Chunk GUID [16 Bytes]	Identifies the type of chunk and the smart feature associated with the chunk. (Note that a smart feature's chuck GUID is not the same as its CSR GUID.)
K+16	Length [4 Bytes]	The chunk's total length in bytes.
K+20	Inverted Length [4 Bytes]	The bitwise complement of the length.

Table 5-1: General Structure of a Chunk

Each chunk ends with a four byte unsigned integer indicating the length of the chunk and four bytes which indicate the bitwise complement of the length. Transferring both the chunk length and the bitwise complement of the length serves as a mechanism to detect transmission errors. If the last four bytes of a chunk aren't the bitwise complement of the preceding four bytes, the chunk's length information isn't valid and this indicates that a transmission error occurred.

There are different types of chunks, for example, the chunk that is added when the cycle time stamp smart feature is enabled and the chunk that is added when the frame counter smart feature is enabled. Although most chunks follow the general structure described in Table 5-1, each type of chunk has unique aspects to its layout. To allow you to distinguish between the chunks, each chunk carries a “chunk GUID”. The GUID for each chunk is transferred just before the chunk’s length information. If you look through the descriptions of the smart features in Section 5.7, you will notice that for smart features which add a chunk to the image data stream, there is a description of the layout of the chunk and the chunk GUID associated with the chunk.

A chunk’s length field contains the chunk’s total length in bytes. The GUID, the length, and the inverted length are included as part of the total chunk length.

By appending length information and a chunk GUID to each chunk, the camera sends a self-describing data stream and allows easy navigation through the individual chunks that make up a complete image data frame.

Don’t confuse CSR GUIDs with chunk GUIDs:

- Each smart feature has a control and status register (CSR) associated with it and each CSR has a unique “CSR GUID” assigned to the register. The CSR GUIDs are used to help you keep track of which CSR is associated with each smart feature.
- Any smart feature that adds a “chunk” of data to the image data stream also has a unique “chunk GUID” assigned to the feature. The chunk GUID will be included the chunk of data that a smart feature adds to the image data. The chunk GUIDs let you determine which smart feature is associated with each added chunk in the image data stream.

The CRC Checksum is an exception to the general structure of a chunk. See Section 5.7.5 for more information.

5.6.1 How Big a Buffer Do I Need?

When smart features that add data to the image are enabled, the size of each transmitted frame will be larger than you would normally expect for a frame which contains only image data. To determine the size of the buffer that you will need to hold an image with appended smart features data, check the Total_Bytes_Hi_Inq and Total_Bytes_Lo_Inq fields of the Format_7 register for the mode you are currently using. Make sure to check these fields after all smart features have been enabled and all other settings affecting the image size have been completed. The size information in these fields will allow you to properly set up buffers to receive the transmitted images.

5.7 Standard Smart Features on the A601f-HDR

5.7.1 Extended Data Stream

The extended data stream feature has two functions:

- When it is enabled, information such as image height, image width, and AOI size is added to the basic pixel data for each image.
- It must be enabled before you can use any other smart feature that adds information to the image data stream.

With the extended data stream feature enabled, the basic pixel data for each image and the added information such as the image height and width are included in an “extended data chunk”. Refer to the extended data chunk layout below for a complete description of the information included in the extended data chunk.

> ⓘ The extended data stream feature must be enabled in order to use any of the other smart feature that adds information to the image data stream. Disabling the extended data stream feature switches off all smart features that add information to the image data stream.
>
> The extended data stream feature and any other smart features which add information to the image data stream will only work when the camera is set for video format 7.

Control and Status Register for the Extended Data Stream Feature

Name	Extended_Data_Stream	
Address	See “Determining the Address of Smart Features CSRs” on page 5-4.	
CSR GUID	4E7ABCB0 - 1B84 - 11D8 - 9651 - 00105A5BAE55	
Field	**Bit**	**Description**
Presence_Inq (Read only)	[0]	Presence of this feature 0: Not Available 1: Available
----	[1 ... 30]	Reserved
Enable (Read / write)	[31]	Enable / Disable this feature 0: Disable 1: Enable

Extended Data Chunk Layout

Position	Name	Description
0	Pixel Data [K Bytes]	The pixel data from the captured image
K	Gap [M Bytes]	For technical reasons, there might be a gap between the pixel data and the other data in the extended image data.

K + M	Stride [4 Bytes]	Signed integer. Indicates the number of bytes needed to advance from the beginning of one row in an image to the beginning of the next row.
K + M + 4	Reserved [3 Bytes]	-----
K + M + 7	Data Depth [1 Byte]	Effective data depth in bits of the pixels in the image.
K + M + 8	Top [2 Bytes]	Y coordinate of the top left corner of the current area of interest (AOI).
K + M + 10	Left [2 Bytes]	X coordinate of the top left corner of the current AOI.
K + M + 12	Height [2 Bytes]	Height in pixels of the current AOI.
K + M + 14	Width [2 Bytes]	Width in pixels of the current AOI.
K + M + 16	Reserved [3 Bytes]	-----
K + M + 19	Color Coding ID [1 Byte]	Color coding ID which describes the pixel data format. See DCAM V1.31. See also Section 3.8.2 of this document.
K + M + 20	Reserved [3 Bytes]	-----
K + M + 23	Color Filter ID [1 Byte]	For color cameras, describes the orientation of the color filter to the current AOI. See DCAM V1.31.
K + M + 24	Chunk GUID [16 Bytes]	94ED7C88 - 1C0F - 11D8 - 82E0 - 00105A5BAE55
K + M + 40	Chunk Length [4 Bytes]	This chunk's total length in bytes.
K + M + 44	Inverted Chunk Length [4 Bytes]	The bitwise complement of the chunk length.

5.7.2 Frame Counter

The frame counter feature numbers images sequentially as they are captured. The counter starts at 0 and wraps at 4294967296 (operating continuously at 100 frames per second, it would take the counter about 500 days to wrap). The counter increments by one for each captured frame. Whenever the camera is powered off, the counter will reset to 0.

Note that if the camera is in continuous shot mode and continuous capture is stopped, up to two numbers in the counting sequence may be skipped. This happens due to the internal image buffering scheme used in the camera.

> ⓘ The extended data stream feature (see Section 5.7.1) must be enabled in order to use the frame counter feature or any of the other smart feature that adds information to the image data stream. Disabling the extended data stream feature switches off all smart features that add information to the image data stream.
>
> The frame counter feature will only work when the camera is set for video format 7.

Control and Status Register for the Frame Counter Feature

Name	Frame_Counter	
Address	See “Determining the Address of Smart Features CSRs” on page 5-4.	
CSR GUID	4433C4A4 - 1B84 - 11D8 - 86B2 - 00105A5BAE55	
Field	**Bit**	**Description**
Presence_Inq (Read only)	[0]	Presence of this feature 0: Not Available 1: Available
----	[1 ... 30]	Reserved
Enable (Read / write)	[31]	Enable / Disable this feature 0: Disable 1: Enable

Frame Counter Chunk Layout

Position	Name	Description
0	Counter [4 Bytes]	The frame counter.
4	Chunk GUID [16 Bytes]	8C5DB844 - 1C0F - 11D8 - 965F - 00105A5BAE55
20	Chunk Length [4 bytes]	This chunk’s total length in bytes.
24	Inverted Chunk Length [4 bytes]	The bitwise complement of the chunk length.

5.7.3 Cycle Time Stamp

The cycle time stamp feature adds a chunk to each image frame containing the value of the counters for the IEEE 1394 bus cycle timer. The counters are sampled at the start of exposure of each image.

> The extended data stream feature (see Section 5.7.1) must be enabled in order to use the cycle time stamp feature or any of the other smart feature that adds information to the image data stream. Disabling the extended data stream feature switches off all smart features that add information to the image data stream.
>
> The cycle time stamp feature will only work when the camera is set for video format 7.

Control and Status Register for the Cycle Time Stamp Feature

Name	Cycle_Time_Stamp	
Address	See "Determining the Address of Smart Features CSRs" on page 5-4.	
CSR GUID	5590D58E - 1B84 - 11D8 - 8447 - 00105A5BAE55	
Field	**Bit**	**Description**
Presence_Inq (Read only)	[0]	Presence of this feature 0: Not Available 1: Available
----	[1 ... 30]	Reserved
Enable (Read / write)	[31]	Enable / Disable this feature 0: Disable 1: Enable

Cycle Time Stamp Chunk Layout

Position	Name	Description		
0	Cycle Time Stamp [4 Bytes]	**Field**	**Bit**	**Description**
		Second Count	[0 ... 6]	Counts the seconds. Wraps to zero after 127 seconds.
		Cycle Count	[7 ... 19]	Counts the 125 µs isochronous bus cycles. Wraps to zero after counting to 7999.
		Cycle Offset	[20 ... 31]	Counts at 24.576 MHz and wraps to zero after counting to 3071 (resulting in a 125 µs cycle)
4	Chunk GUID [16 Bytes]	994DD430 - 1C0F - 11D8 - 8F6B - 00105A5BAE55		
20	Chunk Length [4 Bytes]	This chunk's total length in bytes.		
24	Inverted Chunk Length [4 Bytes]	The bitwise complement of the chunk length.		

5.7.4 DCAM Values

The DCAM values feature adds a chunk to each image frame containing the current settings for some standard DCAM features. The settings are sampled at the start of exposure of each image.

> The extended data stream feature (see Section 5.7.1) must be enabled in order to use the DCAM values feature or any of the other smart feature that adds information to the image data stream. Disabling the extended data stream feature switches off all smart features that add information to the image data stream.
>
> The DCAM values feature will only work when the camera is set for video format 7.

Control and Status Register for the DCAM Values Feature

Name	DCAM_Values	
Address	See “Determining the Address of Smart Features CSRs” on page 5-4.	
CSR GUID	494DE528 - 1B84 - 11D8 - 8A0C - 00105A5BAE55	
Field	**Bit**	**Description**
Presence_Inq (Read only)	[0]	Presence of this feature 0: Not Available 1: Available
----	[1 ... 30]	Reserved
Enable (Read / write)	[31]	Enable / Disable this feature 0: Disable 1: Enable

DCAM Values Chunk Layout

Position	Name	Description		
0	Gain CSR [4 Bytes]	Content of the DCAM Gain CSR		
		Field	**Bit**	**Description**
		Presence_Inq	[0]	Presence of this feature If 0, the DCAM feature is not available and all of its values should be ignored
		Abs_Control	[1]	Absolute control mode If 1, the DCAM feature is in absolute control mode and the current value can be read from the Absolute Value CSR. Otherwise, the Value field holds the current raw value setting.
		-----	[2 ... 4]	reserved
		One_Push	[5]	If 1, a one push operation was in progress.
		ON_OFF	[6]	0: The feature was disabled, ignore the value 1: The feature was enabled
		A_M_Mode	[7]	0: The feature was in manual control mode 1: The feature was in auto control mode
		--	[8 ... 19]	Reserved
		Value	[20 ... 31]	Value of the feature
4	Gain Absolute Value CSR [4 Bytes]	**Field**	**Bit**	**Description**
		Abs Value	[0 ... 31]	Floating point value with IEEE/real*4 format Unit: dB
8	Shutter CSR [4 bytes]	Content of the DCAM Shutter CSR Same layout as the GAIN CSR		
12	Shutter Absolute Value CSR [4 Bytes]	**Field**	**Bit**	**Description**
		Abs Value	[0 ... 31]	Floating point value with IEEE/real*4 format Unit: seconds
16	Gamma CSR [4 bytes]	Content of the DCAM Gamma CSR Same layout as the Gain CSR		
20	Gamma Absolute Value CSR [4 Bytes]	**Field**	**Bit**	**Description**
		Abs Value	[0 ... 31]	Floating point value with IEEE/real*4 format Unit: dB

24	White Balance CSR [4 Bytes]	Content of the DCAM White Balance CSR		
		Field	**Bit**	**Description**
		Presence_Inq	[0]	Presence of this feature If 0, the DCAM feature is not available and all of its values should be ignored
		Abs_Control	[1]	Absolute control mode If 1, the DCAM feature is in absolute control mode and the current value can be read from the Absolute Value CSR. Otherwise, the Value field holds the current raw value setting.
		-----	[2 ... 4]	reserved
		One_Push	[5]	If 1, a one push operation was in progress.
		ON_OFF	[6]	0: The feature was disabled, ignore the value 1: The feature was enabled
		A_M_Mode	[7]	0: The feature was in manual control mode 1: The feature was in auto control mode
		U_Value / B_Value	[8 ... 19]	U value / B value
		V_Value / R_Value	[20 ... 31]	V_Value / R_Value
28	White Balance Absolute Value CSR [4 Bytes]	**Field**	**Bit**	**Description**
		Abs Value	[0 ... 31]	Floating point value with IEEE/real*4 format Unit: K (Kelvin)
32	Brightness CSR [4 bytes]	Content of the DCAM Brightness CSR Same layout as the Gain CSR		
36	Brightness Absolute Value CSR [4 Bytes]	**Field**	**Bit**	**Description**
		Abs Value	[0 ... 31]	Floating point value with IEEE/real*4 format Unit: %
40	Chunk GUID [16 Bytes]	911C8982 - 1C0F - 11D8 - 8AF0 - 00105A5BAE55		
56	Chunk Length [4 bytes]	This chunk's total length in bytes.		
60	Inverted Chunk Length [4 bytes]	The bitwise complement of the chunk length.		

5.7.5 CRC Checksum

The CRC (Cyclic Redundancy Check) Checksum feature adds a chunk to each image frame containing a 16 bit CRC checksum calculated using the Z-modem method. The CRC Checksum chunk is always the last chunk added to the image data stream and the chunk is always 32 bits in size. As shown in Figure 5-2, the checksum is calculated using all of the image data and all of the appended chunks except for the checksum itself.

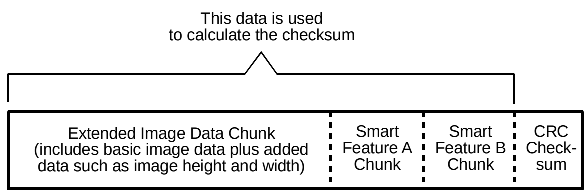

Figure 5-2: Data Used for the Checksum Calculation

The extended data stream feature (see Section 5.7.1) must be enabled in order to use the CRC Checksum feature or any of the other smart feature that adds information to the image data stream. Disabling the extended data stream feature switches off all smart features that add information to the image data stream.

The CRC Checksum feature will only work when the camera is set for video format 7.

The data transmission method used on **A601f-HDR** cameras is extremely reliable. The CRC Checksum feature is included on the camera because CRC checksums are so commonly used with data transmission applications.

Control and Status Register for the CRC Checksum Feature

Name	CRC_Checksum	
Address	See “Determining the Address of Smart Features CSRs” on page 5-4.	
CSR GUID	3B34004E - 1B84 - 11D8 - 83B3 - 00105A5BAE55	
Field	**Bit**	**Description**
Presence_Inq (Read only)	[0]	Presence of this feature 0: Not Available 1: Available
----	[1 ... 30]	Reserved
Enable (Read / write)	[31]	Enable / Disable this feature 0: Disable 1: Enable

CRC Checksum Chunk Layout

The CRC checksum is an exception to the normal chunk structure. The CRC chunk is always 32 bits wide and is always the last chunk appended to the image data. The lower 16 bits of the chunk are filled with the checksum and the upper 16 bits of the chunk are filled with zeros.

Bit	Description
[0 ... 7]	CRC Checksum low byte
[8 ... 15]	CRC Checksum high byte
[16 ... 23]	0x00
[24 ... 31]	0x00

Using the Checksum to Check the Data Integrity

When the checksum smart feature is enabled, the following two C functions can be used to check if an acquired frame contains a valid CRC checksum. The user must pass the acquired image buffer and the buffer's length in bytes to the CheckBuffer() function. The CheckBuffer() function uses the CRC16() function to calculate the checksum.

These two samples are intended to aid you in developing the code for your application. They are provided solely as examples.

```
/** \brief Calculates a 16 bit CRC checksum
  * \param pData Pointer to the data buffer
  * \param nbyLength Size of the buffer in bytes
  * \return The CRC checksum
  */
unsigned short CRC16(const unsigned char *pData, unsigned long nbyLength )
{
    unsigned long i, j, c, bit;
    unsigned long crc = 0;
    for (i=0; i<nbyLength; i++) {
        c = (unsigned long)*pData++;
        for (j=0x80; j; j>>=1) {
            bit = crc & 0x8000;
            crc <<= 1;
            if (c & j) bit^= 0x8000;
            if (bit) crc^= 0x1021;
        }
    }
    return (unsigned short) (crc & 0xffff);
}
```

```
/** \brief Verifies a frame buffer's CRC checksum
  * \param pData Pointer to the frame
  * \param nbyLength Size of frame in bytes
  * \return 1, if the check succeeds, 0 otherwise
  */
int CheckBuffer(const unsigned char* pData, unsigned long nbyLength )
{
       unsigned long nCurrentCRC, nDesiredCRC;
       /* Calculate the CRC checksum of the buffer. Don't take the last four bytes
           containing the checksum into account */
       nCurrentCRC = CRC16(pData, nbyLength - sizeof( unsigned long ) );
       /* Retrieve the desired CRC value from the data buffer */
       nDesiredCRC =  ((unsigned long*) pData)[ nbyLength / sizeof ( unsigned long ) - 1];
       /* Return TRUE if they are equal */
       return nCurrentCRC == nDesiredCRC;
}
```

5.7.6 Test Images

A601f-HDR cameras include a test image mode as a smart feature. 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, the CMOS pixel array, or the ADCs. Test images one, two, three, five and six are available on **A601f-HDR** cameras.

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

ⓘ	The test image smart feature does not add information to the image data stream and can be enabled even when the extended data stream feature (see Section 5.7.1) is disabled. The test image feature will work when the camera is set for any valid video format.

Test Image one

As shown in Figure 5-3, test image one consists of rows with several gray scale gradients ranging from 0 to 255. Assuming that the camera is operating at full 656 x 491 resolution and is set for a monochrome, 8 bit output mode, when the test images are generated:

- row 0 starts with a gray value of 1 for the first pixel,
- row 1 starts with a value of 2 for the first pixel,
- row 2 starts with a gray vale of 3 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 5-3, but the starting pixel values on each row will not be as described above.)

The mathematical expression for test image one is:

$$\text{grayvalue} = [\, x + y + 1 \,]\ \text{MOD256}$$

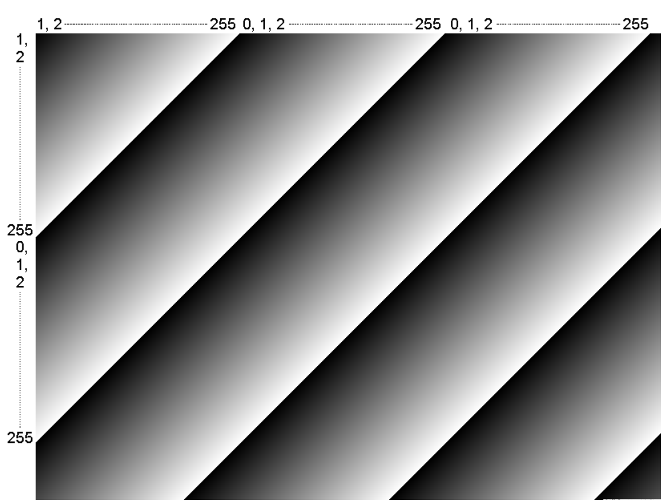

Figure 5-3: Test Image One

Test Image Two

As shown in Figure 5-4, test image two consists of rows with several gray scale gradients ranging from 0 to 255. Assuming that the camera is operating at full 656 x 491 resolution and is set for a monochrome, 8 bit output mode, when the test images are generated:

- rows 0, 1, and 2 start with a gray value of 0 for the first pixel,
- rows 3, 4, 5, and 6 start with a gray value of 1 for the first pixel,
- rows 7, 8, 9, and 10 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 5-4, but the staring pixel values on each row will not be as described above.)

The mathematical expression for test image two is:

$$\text{grayvalue} = \frac{[\,x + y + 1\,]}{4} \text{ MOD } 256, \quad \text{round off all values}$$

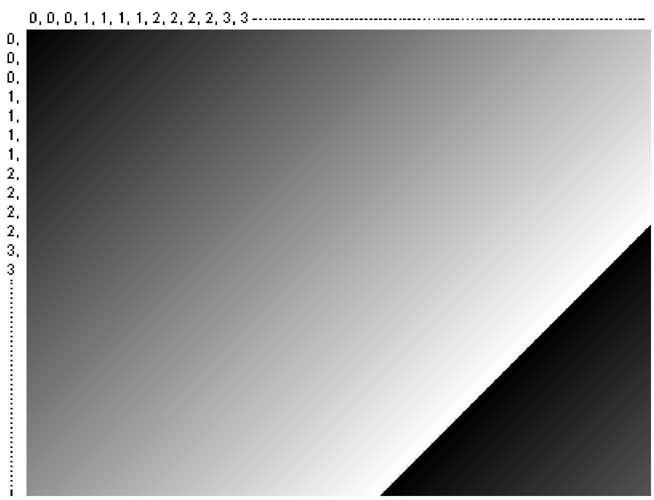

Figure 5-4: Test Image Two

Test Image Three

Test image three 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 or a continuous-shot command signal is sent to the camera.

Test Image Five

Test image five is a stationary image. Figure 5-5 shows the general appearance of test image five. The test image is generated using a complex mathematical formula and its appearance will vary significantly depending on how the HDR parameters are set. The main way that this image can be used is to check the basic functionary of your HDR feature. To check basic HDR functionality, enable test image five and vary the HDR parameters. If you see the appearance of the test image changing as you change the HDR parameters, it means that the basic HDR functions are operational.

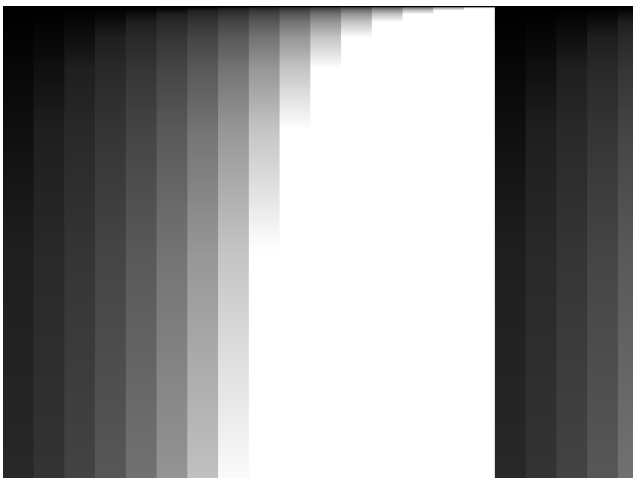

Figure 5-5: Test Image Five

Test Image Six

Test image six is similar to test image five but it is not stationary. The image moves by 1 pixel from right to left whenever a one-shot or a continuous-shot command signal is sent to the camera.

Control and Status Register for the Test Image Feature

Name	Test_Images	
Address	See “Determining the Address of Smart Features CSRs” on page 5-4.	
CSR GUID	2A411342 - C0CA - 4368 - B46E - EE5DEEBF0548	
Field	**Bit**	**Description**
Presence_Inq (Read only)	[0]	Presence of this feature 0: Not Available 1: Available
-----	[1 ... 7]	Reserved
Image_Inq_1 (Read only)	[8]	Presence of test image 1 0: Not Available 1: Available
Image_Inq_2 (Read only)	[9]	Presence of test image 2 0: Not Available 1: Available
Image_Inq_3 (Read only)	[10]	Presence of test image 3 0: Not Available 1: Available
Image_Inq_4 (Read only)	[11]	Presence of test image 4 0: Not Available 1: Available
Image_Inq_5 (Read only)	[12]	Presence of test image 5 0: Not Available 1: Available
Image_Inq_6 (Read only)	[13]	Presence of test image 6 0: Not Available 1: Available
Image_Inq_7 (Read only)	[14]	Presence of test image 7 0: Not Available 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 5: Test image 5 active 6: Test Image 6 active
-----	[19 ... 31]	Reserved

5.7.7 Extended Version Information

A601f-HDR cameras include a register that contains version numbers for the camera's internal software. This information is not ordinarily useful to the camera user. However, for troubleshooting purposes, Basler technical support may ask you to read this register and to supply the results.

> ⓘ The extended version information smart feature does not add information to the image data stream and can be accessed even when the extended data stream feature (see Section 5.7.1) is disabled.
>
> The extended version feature will work when the camera is set for any valid video format.

Control and Status Register for the Extended Version Information Feature

Name	Extended_Version_Information	
Address	See "Determining the Address of Smart Features CSRs" on page 5-4.	
CSR GUID	2B2D8714 - C15E - 4176 - A235 - 6EF843D747B4	
Field	**Bit**	**Description**
Presence_Inq (Read only)	[0]	Presence of this feature 0: Not Available 1: Available
-----	[1 ... 7]	Reserved
Length	[8 ... 15]	Specifies the length in quadlets of the "string" field.
-----	[16 ... 31]	Reserved
Version_Info	[n Bytes]	An ASCII character string that includes the version numbers for the camera's internal software. The length of this string field is equal to the number of quadlets given in the "length" field above.

> ⓘ The ASCII character string in the Version_Info field contains the camera's "firmware ID" number. You can read the string to determine your camera's firmware ID. The ID number's position in the string is described in Section 1.1.

5.7.8 Lookup Table

A601f-HDR cameras have a sensor that reads pixel values at a 10 bit depth, however, the cameras can be set to output pixel values at an 8 bit depth. When set for 8 bit output, the camera normally uses an internal process to convert the 10 bit pixel values from the sensor to the 8 bit values transmitted out of the camera. When making the 10 to 8 bit conversion, the internal process takes the camera's current gain and brightness settings into account.

A601f-HDR cameras include a smart feature that allows you to use a custom lookup table to map the 10 bit sensor output to the 8 bit camera output rather than using the internal process. When the custom lookup table is enabled, the gain and brightness settings have no effect. The 10 to 8 bit conversion is based solely on the lookup table.

The lookup table is essentially just a list of 1024 values. Each value in the table represents the 8 bit value that will be transmitted out of the camera when the sensor reports a particular 10 bit value for a pixel. The first number in the table represents the 8 bit value that will be transmitted out of the camera when the sensor reports that a pixel has a value of 0. The second number in the table represents the 8 bit value that will be transmitted out of the camera when the sensor reports that a pixel has a value of 1. The third number in the table represents the 8 bit value that will be transmitted out of the camera when the sensor reports that a pixel has a value of 2. And so on.

The advantage of the lookup table feature is that it allows the user to customize the response curve of the camera. The graphs below represent the contents of two typical lookup tables. The first graph is for a lookup table where the values are arranged so that the output of the camera increases linearly as the sensor output increases. The second graph is for a lookup table where the values are arranged so that the camera output increases quickly as the sensor output moves from 0 through 511 and increases gradually as the sensor output moves from 512 through 1023.

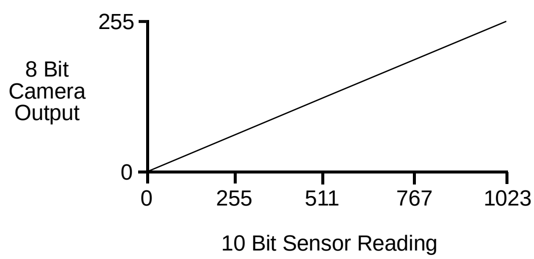

Figure 5-6: LUT with Values Mapped in a Linear Fashion

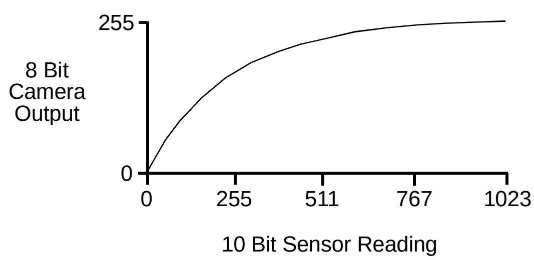

Figure 5-7: LUT with Values Mapped for Higher Camera Output at Low Sensor Readings

Please look at the next page and examine the layout of the control and status register for the lookup table smart feature. You will notice that the first two quadlets of the register include bits that allow you to check for this feature's presence and to enable or disable the feature. These initial two quadlets are followed by 1024 quadlets. The 1024 quadlets contain the values that make up the customized lookup table.

ⓘ	The lookup table smart feature does not add information to the image data stream and can be accessed even when the extended data stream feature (see Section 5.7.1) is disabled. When you enable the lookup table feature, the 1024 quadlets that represent the lookup table are automatically populated with values based on the current gain and brightness settings. If you want use a customized lookup table you must: 1. Use the the look table feature Control and Status Register (CSR) to enable the lookup table feature. 2. Use the CSR to load the values for the customized lookup table. When the lookup table is enabled, changes in the gain and brightness settings will have no effect on camera operation. The lookup table feature will work when the camera is set for any valid video format. The lookup table feature **can not** be used when the high dynamic range feature (see Section 6) is enabled.

Control and Status Register for the Lookup Table Feature

Name	Lookup_Table		
Address	See “Determining the Address of Smart Features CSRs” on page 5-4.		
CSR GUID	B28C667C - DF9D - 11D7 - 8693 - 000C6E0BD1B0		
Position	**Field**	**Bit**	**Description**
0	Presence_Inq (Read only)	[0]	Presence of this feature 0: Not Available 1: Available
	-----	[1 ... 30]	Reserved
	Enable (Read / write)	[31]	Enable / Disable this feature 0: Disable 1: Enable
4	In_Depth_Inq (Read only)	[0 ... 15]	Bit depth of the pixel data reported by the sensor.
	Out_Depth_Inq (Read only)	[16 ... 31]	Bit depth of the pixel data transmitted from the camera.
8	Quadlet_0 (Read / write)	[1 Quadlet]	Defines the 8 bit value that will be transmitted from the camera when the 10 bit pixel value from the sensor is 0. (The 8 LSBs of the quadlet carry the data for the field. The 24 MSBs are all zeros.)
12	Quadlet_1 (Read / write)	[1 Quadlet]	Defines the 8 bit value that will be transmitted from the camera when the 10 bit pixel value reported from the sensor is 1.
16	Quadlet_2 (Read / write)	[1 Quadlet]	Defines the 8 bit value that will be transmitted from the camera when the 10 bit pixel value reported from the sensor is 2.
• • •	• • •	• • •	• • •
4096	Quadlet_1022 (Read / write)	[1 Quadlet]	Defines the 8 bit value that will be transmitted from the camera when the 10 bit pixel value reported from the sensor is 1022.
4100	Quadlet_1023 (Read / write)	[1 Quadlet]	Defines the 8 bit value that will be transmitted from the camera when the 10 bit pixel value reported from the sensor is 1023.

5.7.8.1 Using the SFF Viewer to Upload a Lookup Table

The Configurator window in the Basler SFF Viewer (see Section 5.4) includes an *Upload* button that can be used to easily load a file containing a customized lookup table into the camera. The file must be plain text and must be formatted correctly. The file must have 1024 lines with each line containing two comma-separated values. The first value on each line represents a 10 bit pixel reading from the sensor and the second value represents the corresponding 8 bit output that will be transmitted from the camera.

The sample below shows part of a typical text file for a lookup table. Assuming that you have enabled the lookup table feature on your camera and used the *Upload* button to load a file similar to the sample into the camera:

- If the sensor reports that a pixel has a value of 1, the camera will output a value of 0.
- If the sensor reports that a pixel has a value of 6, the camera will output a value of 1.
- If the sensor reports that a pixel has a value of 1019, the camera will output a value of 254.

```
0,0
1,0
2,0
3,0
4,1
5,1
6,1
7,1
8,2
9,2
10,2
11,2
12,3
13,3
14,3
15,3
16,4
17,4
18,4
19,4
20,5
21,5
```

```
1010,252
1011,252
1012,253
1013,253
1014,253
1015,253
1016,254
1017,254
1018,254
1019,254
1020,255
1021,255
1022,255
1023,255
```

Figure 5-8: Sample Text File for Use With *Upload* Button

5.8 Customized Smart Features

The Basler **A601f-HDR** has significant processing capabilities and Basler can accommodate customer requests for customized smart features. A great advantage of the smart features framework is that it serves as a standardized platform for parameterizing any customized smart feature and for returning the results from the feature.

The Basler camera development team is ready and able to handle requests for customized smart features. The cost to the customer for adding a customized smart feature to the **A601f-HDR** will depend on the complexity of algorithm, software, and firmware development, of incorporating the feature within the smart features framework, and of testing to ensure that the feature meets specifications. Please contact your Basler sales representative for more details about customized smart features.

6 Using the HDR Feature

6.1 What is the HDR Feature

Most digital cameras operate with sensors that use an 8, 10, or 12 bit value to encode the brightness of each pixel in the images captured by the sensor. If the sensor operates in a linear fashion with a 12 bit depth, it can capture images with a dynamic range of up to 72 dB between the darkest area in the image and the lightest area in the image. For many applications where the light sources in the field of view can be adjusted, this range is usually enough to accurately represent all of the gradations of shading within the image. But for situations where a bright light source or shiny materials are located within the field of view or where a scene is captured in daylight, this dynamic range may not be enough. In these situations, you will often find that if a high exposure time is used to capture detail in the darker areas of the field of view, the light areas appear overexposed in the captured images. And if a short exposure time is used to avoid overexposure in the lighter areas of the captured images, all detail is lost in the darker areas. The basic problem is that the very wide range of lighting gradations present in these situations can not be accurately represented by an 8, 10, or 12 bit output.

For situations where the lighting ranges from very dark to very light, a digital camera that can output detailed images on a scale which represents a very high dynamic range is required. The **A601f-HDR** has this capability. Technically, it can output images at up to a 22 bit depth - a scale that can represent images with up to a 132 dB dynamic range. (In practice, you will find the useful limit to be about 19 bits and an approximately 112 dB dynamic range.)

6.2 How Does the HDR Feature Work

The principle behind the HDR feature is fairly simple. When an HDR image capture is triggered on the camera, the camera actually captures several complete images at progressively longer exposure times. In the images with the shortest exposure times, the bright areas will be sharp and clear but the dark areas will be underexposed and details will be lost. In the images with the longest exposure times, the bright areas will be overexposed but the dark areas will be clear and will show detail. The HDR algorithm examines the collected set of images and for each pixel in the scene, it selects the pixel value from the collected images that best represents the scene. It them merges these pixel values into a single image and scales the pixel values in the combined image to an output range of up to 22 bits.

> ⓘ Internally, the camera captures several images to create one HDR image. Externally, the camera behaves as though it is capturing a single image. In other words, for each complete HDR image, only one trigger ready signal is generated, only one trigger signal is needed to start image capture, the frame counter increments only once, etc.

The three images below show what can be done with the **A601f-HDR** when capturing an image outside in daylight. The left image was captured in standard, single-exposure fashion with a low exposure time. As you can see, the bright areas of the image are visible, but the dark areas have no detail. The center image was captured in standard, single-exposure fashion with a longer exposure time. The dark areas now show detail, but the bright areas are overexposed. The right image was captured using the **A601f-HDR** high dynamic range feature. As you can see, the image shows good detail in both the dark areas and the light areas. (You should know that a filter was used to reduce the right-hand image to 8 bits so that it could be viewed and printed on conventional devices.)

Figure 6-1: Conventional vs. **A601f-HDR** Images

One major advantage of the multiple exposure technique employed in **A601f-HDR** cameras is that the high dynamic range images produced have a low noise level. There are cameras available on the market that can produce high dynamic range images from a single exposure, but the techniques used to stretch the dynamic range in the images from these cameras results in a high noise level.

> ⓘ Due to the multiple exposure technique employed in **A601f-HDR** cameras, high dynamic range images of moving objects may contain image artifacts.

6.3 Using the HDR Feature

6.3.1 Enabling and Parameterizing the HDR Feature

The HDR feature can only work when the camera is set for video format 7, mode 2. Make sure that the camera is set for this format and mode before enabling HDR (see pages 3-19 and 4-11).

The HDR feature on **A601f-HDR** cameras is part of the smart features framework described in Chapter 5. If you have not already done so, you should read the material in this chapter to familiarize yourself with smart features. The HDR feature is enabled and its parameters are set in the same fashion as the other smart features. The layout of the control and status register (CSR) for the HDR feature is shown in the table starting on page 6-6.

ⓘ	The HDR smart feature does not add information to the image data stream and it can be enabled even when the extended image data feature (see Section 5.7.1) is disabled. The HDR feature will only work when the camera is set for video format 7, mode 2.

The main parameters associated with the HDR feature are:

Quality

The quality parameter setting determines the number of exposures that will be captured and combined to form the final images. There are four quality settings: High, Normal, Medium, and Low. The higher the quality setting, the greater the number of exposures used to create each HDR image.

Using higher quality settings represents a trade-off. When you use the higher settings, you will see very low noise in your HDR images (see Figure 6-2 on the next page). At lower settings, the noise in the HDR images increases. But since higher quality images require more exposures to create, the frame rate you can achieve with the high quality settings will be low. Using the lower quality settings will increase your achieveable frame rate, but there will be more noise in the HDR images.

The setting for the quality parameter has an influence on the step size of the dynamic bits parameter (see “Dynamic Bits” below).

Dynamic Bits

The dynamic bits parameter setting determines the bit depth of the HDR images created by the camera. For example, when the dynamic bits is set to 18, the HDR images created by the camera will have an 18 bit depth.

The absolute maximum for the dynamic bits setting is 22, however, the maximum may be limited by other settings. For example, as the value of the start shutter parameter is increased, the maximum allowed value for the dynamic bits setting decreases. Before setting the dynamic bits, you should set all other HDR parameters. You should then check the values of the minimum dynamic bits and maximum dynamic bits parameters. Your setting for the dynamic bits parameter must be between the indicated min and max (inclusive).

While the setting for the dynamic bits parameter determines the bit depth of the HDR images created by the camera, it does not necessarily determine the bit depth of the images transmitted from the camera. See Section 6.3.2 for more details.

The step size that you can use when changing the dynamic bits setting depends on the setting for the quality parameter:

- If the quality parameter is set to “high”, the dynamic bits parameter can be set is steps of one (8, 9, 10, 11, 12 .... 20, 21, 22)
- If the quality parameter is set to “normal”, the dynamic bits parameter can be set is steps of two (8, 10, 12, 14 .... 20, 22)
- If the quality parameter is set to “medium”, the dynamic bits parameter can be set is steps of three (8, 11, 14, 17, 20)
- If the quality parameter is set to “low”, the dynamic bits parameter can be set is steps of four (8, 12, 16, 20)

If the dynamic bits parameter is set to a value that is not valid with the current quality setting, the camera will automatically change the dynamic bits setting to the next highest valid value. For example, if the quality parameter is set to medium and you set the dynamic bits to 12, the camera will automatically increase the dynamic bits setting to 14.

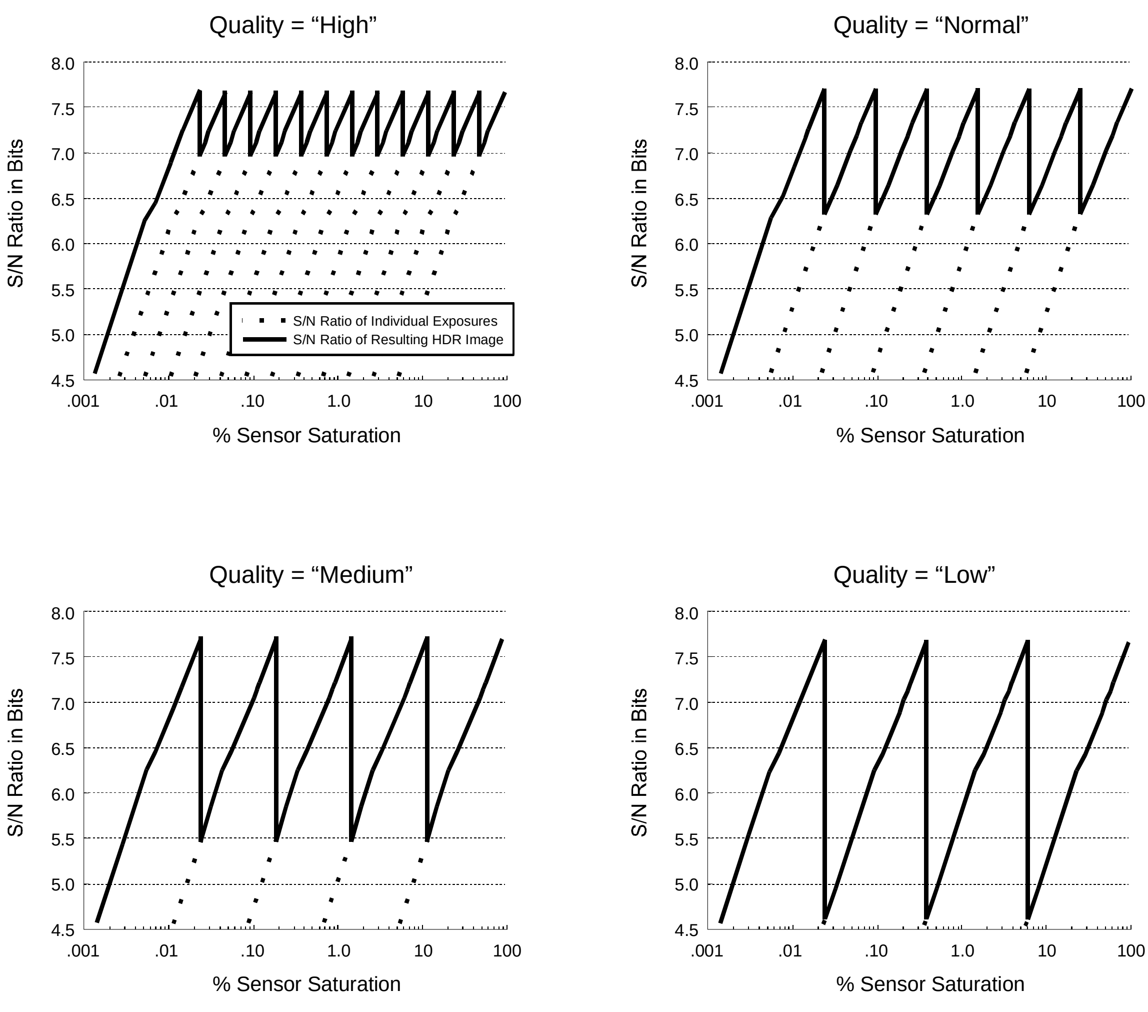

Figure 6-2: Signal-to-Noise Ratio of HDR Images with a 20 Bit Depth

Start Shutter

The HDR feature creates high dynamic range images by capturing a series of images at progressively longer exposure times and then combining the series of images into a single HDR image. The setting for the start shutter parameter determines the exposure time for the first image in the series. The camera automatically calculates the exposure time for the other images in the series based on the start shutter value.

The maximum allowed setting for start shutter can vary depending on other HDR settings. So before you set the start shutter parameter, you should check the values of the minimum start shutter and maximum start shutter parameters. Your setting for the start shutter parameter must be between the indicated min and max (inclusive).

The value of the start shutter parameter represents *n* in the equation:

Starting Shutter Time = (n x 20 µs)

So, for example, if the value stored for the start shutter parameter is 5, the starting shutter time will be 5 x 20 µs or 100 µs.

Increasing the value of the start shutter parameter will increase the brightness of the resulting HDR image. You should keep in mind that changes to the start shutter parameter have an effect on the allowed range of the dynamic bits setting. As the start shutter parameter is increased, the maximum allowed setting for the dynamic bits parameter decreases.

The start shutter parameter setting also affects the maximum frame rate that the camera can achieved. As the start shutter value is increased, the maximum achievable frame rate decreases.

Gamma

When the camera's color coding (see pages 3-19 and page 4-11) is set to Mono 8, the HDR images created by the camera will be converted to 8 bit images before they are transmitted. A common gamma conversion formula is used to convert the images. The setting for the gamma parameter determines the value of gamma in the conversion formula. Section 6.3.2 explains the conversion process in more detail.

The units for the gamma parameter are in hundredths. So if the gamma parameter is set to 75, for example, this represents an actual gamma value of 75 hundredths or 0.75. A setting of 125 would represent 125 hundredths or 1.25.

Before you set the gamma parameter, you should then check the values of the minimum gamma and maximum gamma parameters. Your setting for the gamma parameter must be between the indicated min and max (inclusive).

As mentioned above, this "internal" gamma conversion function is performed inside of the camera before the images are transmitted. You should be aware that this internal function only produces an approximated gamma. Images produced using this internal gamma function are intended for preview purposes when only an 8 bit monitor is available. These images have limited suitability for high level image analysis purposes.

The Basler SFF Viewer includes a converter option that lets you do a gamma conversion on HDR images after they have been transmitted to the PC (see Section 6.3.4). This "external" conversion process gives much better results.

One Push Auto

The one push auto parameter is used to initiate a routine that automatically sets the camera's HDR parameters. Setting the one push auto parameter to 1 initiates the routine. The parameter will automatically reset to zero when the routine is complete.

When the one push auto routine is activated, the camera begins capturing and examining images. As it examines the captured images, it automatically adjusts the HDR settings so that the bright parts of the captured scene are not saturated and the dark parts are not too dark.

Once the routine is complete, the camera will use the new HDR settings made by the routine. The camera will continue to use these settings until you change them.

Control and Status Register for the High Dynamic Range Feature

Name	High_Dynamic_Range		
Address	See "Determining the Address of Smart Features CSRs" on page 5-4.		
CSR GUID	93F1F19D - 5761 - 4260 - A9D787F7BE722129		
Position	**Field**	**Bit**	**Description**
0	Presence_Inq (Read only)	[0]	Presence of this feature 0: Not Available 1: Available
	-----	[1]	Reserved
	One_Push_Auto (Read / write)	[2]	One push automatic parameter adjustment. Setting the bit to 1 will initiate the automatic adjustment routine. The bit will reset to zero when the routine is complete.
	-----	[3]	Reserved
	Quality (Read / write)	[4 ... 5]	Determines the number of exposures that will be captured to create the final image. Higher quality requires more exposures. 0: High Quality 1: Normal Quality 2: Medium Quality 3: Low Quality
	-----	[6 ... 7]	Reserved
	Min_Dynamic_Bits (Read only)	[8 ... 15]	Minimum allowed value for the dynamic bits setting
	Max_Dynamic_Bits (Read only)	[16 ... 23]	Maximum allowed value for the dynamic bits setting
	Dynamic_Bits (Read / write)	[24 ... 31]	Sets the depth of the HDR image
4	Min_Start_Shutter (Read only)	[0 ... 31]	Minimum allowed value for the starting shutter setting

8	Max_Start_Shutter (Read only)	[0 ... 31]	Maximum allowed value for the starting shutter setting
12	Start_Shutter (Read / write)	[0 ... 31]	Starting shutter time = (start_shutter register value x 20 µs)
16	Internal_Gamma Presence_Inq (Read only)	[0]	Presence of the internal gamma feature 0: Not Available 1: Available (This bit is only set when the color coding is set to Mono 8.)
	-----	[1 ... 7]	Reserved
	Min_Gamma (Read only)	[8 ... 15]	Minimum allowed value for the gamma setting
	Max_Gamma (Read only)	[16 ... 23]	Maximum allowed value for the gamma setting
	Gamma (Read / write)	[24 ... 31]	This parameter sets the value of gamma in the conversion formula used when the camera is set for Mono 8 output. The units for this parameter are 1/100ths. So a setting of 75, for example, would represent 75/100ths or 0.75.

When HDR is active, the brightness and gain settings for the camera are fixed and can not be adjusted.

When HDR is active, the shutter setting (see page 4-7) is not used and changing this setting will have no effect on the camera's operation.

6.3.2 Determining the Bit Depth of Transmitted HDR Images

As described in Section 6.3.1, the bit depth of the HDR images created by the camera will be determined by the setting of the Dynamic Bits parameter. While this setting determines the bit depth of the HDR image the camera creates, it does not determine the bit depth of the images that are transmitted out of the camera. The bit depth of the transmitted images is determined by the setting for the Color_Coding_ID in the camera's Format_7 Mode_2 control and status register (see pages 3-19 and 4-11).

When the camera is operating in video Format_7 Mode_2, three color codings are available: Mono 8, Mono 16, and Vendor Specific 0.

With the color coding set to Mono 8:

The HDR images created by the camera are reduced to 8 bit depth before they are transmitted. A common gamma correction method is used to reduce the bit depth. With this "internal" gamma conversion method, each HDR pixel value is converted to an 8 bit value using the following formula:

$$P_8 = 255 \times \left(\frac{P_{HDR}}{P_{HDR\ Max}} \right)^{\gamma}$$

Where: P_8 is the resulting 8 bit pixel value

P_{HDR} is the original pixel value in the HDR image

$P_{HDR\ Max}$ is the maximum pixel value that can be represented in the HDR image with the current HDR settings

γ is the current setting for the gamma parameter in the HDR CSR register

This "internal" gamma conversion function is performed inside of the camera before the images are transmitted. You should be aware that this internal function only produces an approximated gamma. Images produced using this internal gamma function are intended for preview purposes when only an 8 bit monitor is available. These images have limited suitability for high level image analysis purposes.

The Basler SFF Viewer includes a converter option that lets you do a gamma conversion on HDR images after they have been transmitted to the PC (see Section 6.3.4). This "external" conversion process gives much better results.

With the color coding set to Mono 16:

Images are transmitted from the camera at 16 bit depth.

If the bit depth of the HDR images created by the camera is lower than 16 bits, the 16 bit values transmitted from the camera will be packed with zero(s). For example, assume that the bit depth of the HDR images is set to 14 bits. In this case the camera would transmit 16 bit values but only the 14 LSBs would represent actual pixel data. The two MSBs in the 16 bit values transmitted from the camera would be packed with zeros.

With the color coding set for Vendor Specific 0:

Images are transmitted from the camera at 16 bit depth, however the transmitted 16 bits are in a special vendor unique format. This 16 bit format is capable of representing any pixel value present in any HDR image created by the camera.

With the Vendor Specific 0 format, the least significant byte of the transmitted 16 bits represents a base (unsigned) and the most significant byte represents an exponent. The actual value of the pixel is:

$$\text{Actual Pixel Value} = \text{Base} \times 2^{\text{exponent}}$$

Example 1

If an **A601f-HDR** camera was set for Vendor Specific 0 color coding and it transmitted a value of 0x0220, the base would be 32 (decimal) and the exponent would be 2 (decimal). The actual pixel value would be:

$$\text{Actual Pixel Value} = 32 \times 2^{2}$$

$$\text{Actual Pixel Value} = 128$$

Example 2

If an **A601f-HDR** camera was set for Vendor Specific 0 color coding and it transmitted a value of 0x0DC3, the base would be 195 (decimal) and the exponent would be 13 (decimal). The actual pixel value would be:

$$\text{Actual Pixel Value} = 195 \times 2^{13}$$

$$\text{Actual Pixel Value} = 1597440$$

Note that the values delivered from the camera are not normalized. This means that there can be different codings for the same value. For example:

$$128 \times 2^{0} = 64 \times 2^{1} = 32 \times 2^{2} = \ldots$$

6.3.3 Maximum Frame Rate in the HDR Mode

As a rule, the maximum frame rate on an **A601f-HDR** camera is 60 frames per second. The camera can not exceed this frame rate under any circumstances.

The maximum frame rate can also be limited by either of two factors:

- The amount of time it takes to transfer an image from the frame buffer to the PC via the IEEE 1394 bus.
- The amount of time it takes to create an HDR image with the current HDR and AOI settings.

To determine the maximum frame rate for a given set of HDR parameter values, calculate a result in each of the two formulas below. The formula that returns the lowest value will determine the maximum frame rate for the given HDR settings.

Formula 1:

$$\text{Max. Frames/s} = \frac{1}{\text{Packets/frame} \times 125\ \mu s}$$

Formula 2:

This formula includes a series of calculations needed to determine the time it takes to create an HDR image with the current settings.

Calculation A - Number of Exposures Needed to Create the HDR Image:

$$\text{Number of Exposures} = \frac{(DB - 8)}{Q} + 1$$

Where: DB = the dynamic bits setting

Q = 1 with quality set to high

2 with the quality set to normal

3 with the quality set to medium

4 with the quality set to low

Calculation B - Sensor Readout Time for Each Exposure:

$$\text{Readout Time} = (\text{AOI Height} + 3) \times 15.28\ \mu s$$

(The sensor readout time will be the same for each exposure.)

Calculation C - The Exposure Time for Each Exposure

$$\text{Exposure Time}_n = S \times (2^Q)^n$$

Where: S = start shutter setting in µs

Q = 1 with quality set to high

2 with the quality set to normal

3 with the quality set to medium

4 with the quality set to low

n = the exposure number

This calculation must be made for each exposure needed to create the HDR image. The exposures are numbered starting with 0. So, for example, if the HDR image requires three exposures, you will make the calculation for exposure number 0, exposure number 1, and exposure number 2.

Calculation D

For each exposure:

- determine the sum of Exposure Time + 90 µs
- compare this sum to the readout time + 60 µs
- make note of the higher of the two values

Calculation E

Find the sum of the high values that you noted in calculation D. This sum is THDR, i.e., the total time (in µs) that it takes to create one HDR image with the current settings.

Calculation F - The maximum frame rate with the current HDR settings

$$\text{Max. Frames / s} = \frac{1}{\text{THDR}}$$

Once you have made these calculations, you can determine the maximum frame rate for your current HDR settings. Compare the outcome of formula one, the outcome of the calculations in formula two, and the 60 fps absolute maximum rate for the **A601f-HDR**. The maximum frame rate for your current HDR settings is the lowest of these three values.

Example:

Assume that after making all camera settings, you check the Packet_Per_Frame_Inq register in the control and status registers for Format 7. You find that the packets per frame with the current setting is 158.

Assume that the AOI is set for the sensor's full 656 x 491 resolution.

Assume that the HDR settings are:

Quality = Normal (2)

Dynamic Bits = 18

Starting Shutter = 40 µs

Formula 1:

$$\text{Max. Frames/s} = \frac{1}{158 \times 125\ \mu s}$$

Max. Frames/s = 50.6

Formula 2:

Calculation A - Number of Exposures Needed to Create the HDR Image:

$$\text{Number of Exposures} = \frac{(18 - 8)}{2} + 1$$

Number of Exposures = 6

Calculation B - Sensor Readout Time for Each Exposure:

$$\text{Readout Time} = (491 + 3) \times 15.28\ \mu s$$

Readout Time = 7548.32 µs (round to 7548)

(This readout time will be the same for all exposures.)

Calculation C - The Exposure Time for Each Exposure

$$\text{Exposure Time for Exposure}_0 = 40\ \mu s \times (2^2)^0$$

$$\text{Exposure Time for Exposure}_0 = 40\ \mu s$$

$$\text{Exposure Time for Exposure}_1 = 40\ \mu s \times (2^2)^1$$

$$\text{Exposure Time for Exposure}_1 = 160\ \mu s$$

$$\text{Exposure Time for Exposure}_2 = 40\ \mu s \times (2^2)^2$$

$$\text{Exposure Time for Exposure}_2 = 640\ \mu s$$

$$\text{Exposure Time for Exposure}_3 = 40\ \mu s \times (2^2)^3$$

$$\text{Exposure Time for Exposure}_3 = 2560\ \mu s$$

$$\text{Exposure Time for Exposure}_4 = 40\ \mu s \times (2^2)^4$$

$$\text{Exposure Time for Exposure}_4 = 10240\ \mu s$$

$$\text{Exposure Time for Exposure}_5 = 40\ \mu s \times (2^2)^5$$

$$\text{Exposure Time for Exposure}_5 = 40960\ \mu s$$

Calculation D

	Readout Time + 60 µs	Exp. Time + 90 µs	Higher Value
Exposure 0	7548 + 60 = 7608 µs	40 + 90 = 130 µs	7608 µs
Exposure 1	7548 + 60 = 7608 µs	160 + 90 = 150 µs	7608 µs
Exposure 2	7548 + 60 = 7608 µs	640 + 90 = 730 µs	7608 µs
Exposure 3	7548 + 60 = 7608 µs	2560 + 90 = 2650 µs	7608 µs
Exposure 4	7548 + 60 = 7608 µs	10240 + 90 = 10330 µs	10330 µs
Exposure 5	7548 + 60 = 7608 µs	40960 + 90 = 41050 µs	41050 µs

Calculation D

Sum the high values from calculation 4 to get the total HDR exposure time.

Sum = 7608 µs + 7608 µs + 7608 µs + 7608 µs + 10330 µs + 41050 µs

Sum = 81812 µs

Calculation E - The maximum frame rate with the current HDR settings

$$\text{Max. Frames / s} = \frac{1}{81812\ \mu s}$$

Max. Frames / s = 12.2

Among the three values:

- 60 fps maximum frame rate for the A601-HDR
- 50.6 fps from formula 1
- 12.2 fps from formula 2

the lowest value is 12.2. So the maximum frame rate with the current HDR settings is 12.2 frames per second.

6.3.4 Viewing HDR Images with Basler's SFF Viewer

Most common computer monitors can only display images at 8 bits per pixel in grayscale mode. Because HDR images captured by your camera and transmitted to your PC normally have greater than 8 bit depth, they can't usually be displayed on a standard computer monitor. The Basler SFF Viewer (see Section 5.4) includes converters that can be used to reduce captured HDR images to 8 bit depth so that they can be viewed on a standard monitor. Three conversion methods are available in the viewer: Gamma, Tonemap, and Laplace.

The Configurator window in the SFF Viewer software is used the select the conversion method and the Viewer window is used to view the resulting images. For more information on using the SFF Viewer, see the online help file included with the software.

> ⓘ The converters were developed so that the HDR images captured by **A601f-HDR** cameras could be reduced to 8 bit depth for viewing on standard monitors. But these converters are also useful on other Basler IEEE 1394 cameras that do not have the HDR feature. For example, the Basler **A102f** can output images with an effective 12 bit depth. The HDR converters in the SFF Viewer can be used to reduce the 12 bit images to 8 bits so that they can be viewed on a standard monitor.

Gamma Conversion

A common gamma filter is the most simple method for converting captured HDR images to 8 bit depth for on-screen display. With this method, each HDR pixel value is converted to an 8 bit value using the following formula:

$$P_8 = 255 \times \left(\frac{P_{HDR}}{P_{HDR\ Max}}\right)^{\gamma}$$

Where: P_8 is the resulting 8 bit pixel value

P_{HDR} is the original pixel value in the HDR image

$P_{HDR\ Max}$ is the highest pixel value in the captured HDR (or 255 if the highest value is less than 255)

γ is the current value in the Gamma setting in the Configurator window of the viewer

You can use the Configurator window in the software tool to set the value of gamma.

Tonemap Conversion

The tonemap converter adjusts the histogram of the values in the HDR image so that the result is an 8 bit grayscale image with a nearly balanced histogram.

Laplace Conversion

With a Laplace conversion, bandpass filtering is used to decompose the HDR image into several subimages with different spatial frequency ranges. These subimages are then compressed. The subimages with low frequencies are compressed more to “eliminate” global light distribution. The high frequency subimages, which contain most of the details of the scene, are compressed less. The subimages are then recombined to form a single 8 bit image.

The Laplace conversion technique has several advantages and disadvantages. The advantages are that it is a quick conversion (when compared to the most sophisticated filter algorithms) making it good for live viewing and that it has the most highly detailed contrast of any of the implemented converters. The main disadvantage is that the resulting images look “unnatural”.

Gamma Filtered　　Tonemap Filtered　　Laplace Filtered

Figure 6-3: Filtered Images of an Outdoor Scene

6.3.5 “Manually” Adjusting the HDR Settings with Basler’s SFF Viewer

This section describes a technique for “manually” adjusting the HDR settings while capturing and viewing images with the Basler SFF Viewer (see Section 5.4). Doing the “manual” adjustment procedure serves two purposes:

- It familiarizes you with the HDR settings and gives you a feel for how the settings affect the HDR images transmitted from the camera.
- It gives you the opportunity to establish some base HDR settings that you can use when operating the camera in your actual application.

To perform the manual adjustment, you must use the SFF Software Tool to change the HDR settings and to view the captured images. The Configurator window in the software tool is used to change the camera’s HDR settings. The Configurator window is also used to select a conversion method that will be used convert the HDR images to an 8 bit format that is viewable on your monitor. The Viewer window in the software tool is used to view the captured images. (See the online help included with the software tool for more information about using each window.)

To adjust the HDR settings:

1. Set up your lighting and your field of view so that they represent your normal operating conditions.
2. Use the Configurator window to make the following settings:
   - Video Mode = 2
   - Color Coding = Vendor Specific 0,
   - HDR Quality = high
   - HDR Start Shutter = 1
   - HDR Dynamic Bits = 8
   - HDR Converter Type = Tone Map
3. Capture an image and use the Viewer window to examine the pixel values in the brightest parts of the image. The pixel values in these areas should be about 240 to 250. (if you place the cursor over the image, the values for the pixel under the cursor will be displayed in the Viewer window’s status bar.)
   a) If the pixel values are not in that range, use the Configurator window to adjust the HDR starting shutter value. Increasing the value will make the brightest pixel values in the captured images higher. Decreasing the value will make them lower.

      (You could also adjust the image brightness by increasing or decreasing the lighting on your object.)

   b) Continue to capture images, examine the pixels, and adjust the starting shutter value until the brightest pixels are in the 240 to 250 range.
4. Use the Configurator window to increase the HDR dynamic bits setting by 1 and then capture a new image. You should notice that increasing the setting makes the detail in the dark parts of the image become more visible.
   a) Continue increasing the dynamic bits setting by 1, capturing an image, and examining the image until the detail in the dark parts is at an acceptable level.

      (When you are adjusting the dynamic bits setting, you may notice that the maximum for the setting is lower than the technically achieveable value of 22 that you might expect. You should be aware that increasing the starting shutter setting has an effect on the maximum setting for dynamic bits. As you increase the starting shutter setting, the maximum allowed setting for dynamic bits will decrease.)

5. Use the Configurator window to place the camera in continuous capture mode and note the frame rate. This frame rate represents the maximum rate that can be achieved with the current HDR settings. If the frame rate is too low to meet your needs, you can make the following changes to increase the maximum rate:

   a) Decrease the quality setting. Decreasing the quality setting by one level will significantly increase the maximum allowed frame rate. Decreasing the quality level will also increase the noise level in the image, however, the increase in noise level is minimal.

      (You should be aware that when you decrease the quality setting, the number of valid dynamic bit settings becomes more limited. See the descriptions of the quality setting and the dynamic bits setting on page 6-3 for more information.)

   b) Decrease the dynamic bits setting. Decreasing the dynamic bits setting will increase the maximum allowed frame rate. Decreasing the dynamic bits setting will cause the dark parts of the image to lose detail.

   After you make a change to either the quality setting or the dynamic bits setting, check the frame rate to see if it now meets your needs.

6.3.6 HDR Test Images

Two test images (test images five and six) are available for checking the basic functionality of the HDR feature. See Section 5.7.6 for more information on test images.

7 Mechanical Considerations

7.1 Camera Dimensions

The camera housing for the **A601f-HDR** is manufactured with high precision. Planar, parallel, and angular sides guarantee precise mounting with high repeatability.

A601f-HDR cameras are equipped with four M3 mounting holes on the bottom and two M3 mounting holes on the top as indicated in Figure 7-1.

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

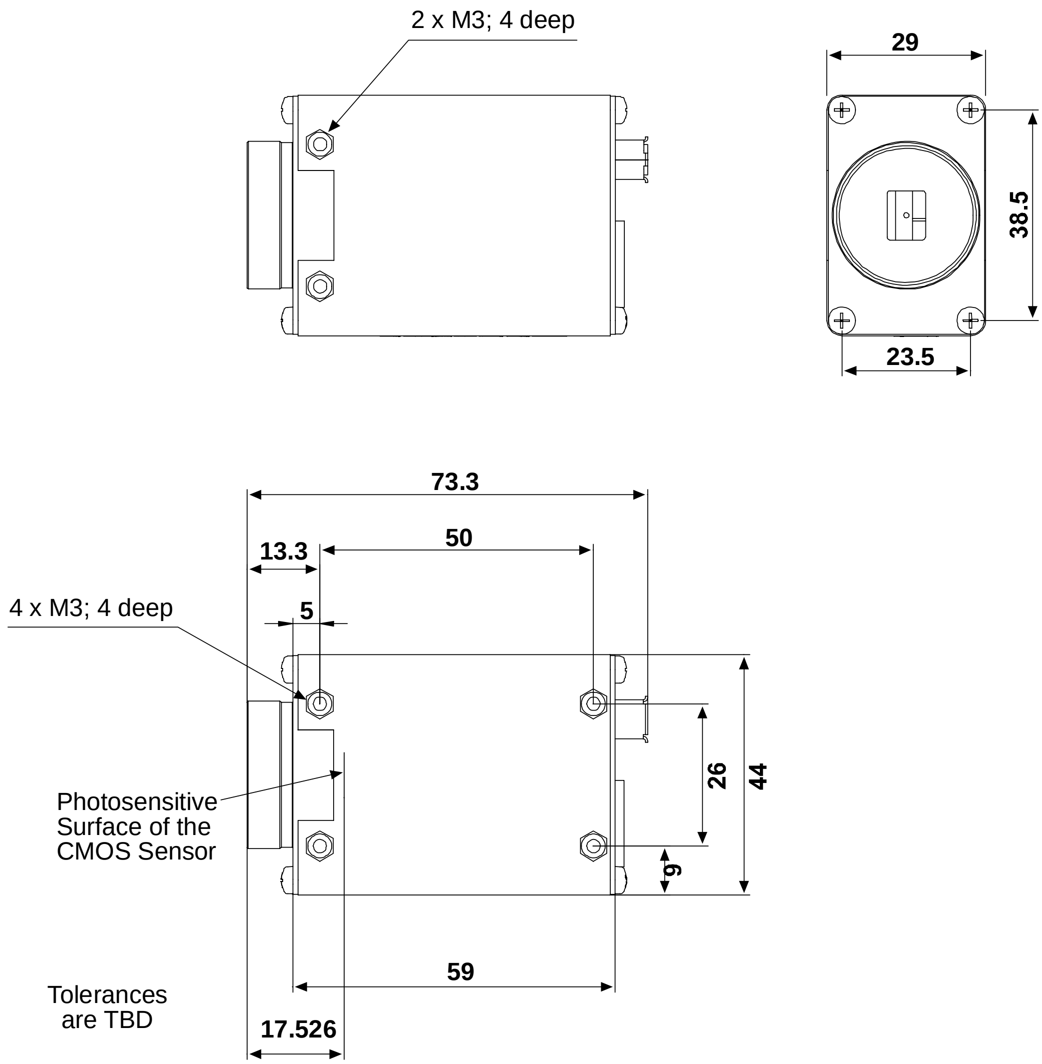

Figure 7-1: **A601f-HDR** Mechanical Dimensions (in mm)

Revision History

Doc. ID Number	Date	Changes
DA00065901	9 March 2004	Initial release of this manual. This revision of the manual applies to cameras with firmware ID 19.
DA00065902	22 March 2004	Expanded the description of the Gain and Brightness functions in Section 3.5.

Feedback

Your feedback will help us improve our documentation. Please click the link below to access an online feedback form. Your input is greatly appreciated.

http://www.baslerweb.com/umfrage/survey.html

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