TECHNICAL MANUAL FOR DVC-16000 CAMERAS

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1. Introduction

The DVC-16000 cameras are based on the Kodak KAI-16000 interline CCD, which provides 4904x3280 pixel resolution and 7.4 µm square pixels with high quantum efficiency and low noise. The DVC-16000 is offered in both standard and cooled configurations, with a choice of Gigabit Ethernet or Camera Link interface.

Additionally, the DVC-16000 is bundled with the full complement of DVC software. For developers, DVC also offers a software developer's kit, which includes a comprehensive API to streamline the integration of any DVC camera into your system. After software installation, the SDK can be found in the /dvcco/docs directory.

For end-users, the DVCView imaging application provides full control of up to 8 cameras simultaneously through an intuitive user interface, and it allows the user to acquire, pan, zoom, analyze, and save imagery and metadata. DVCView also provides direct-to-disk video streaming, time-lapse capture, image averaging, image background subtraction, and flat-fielding.

This manual is a functional overview of the camera, and it is meant to be a companion to the DVCView User Manual and the SDK.

2. Receiving and Unpacking

Your DVC-16000 camera was thoroughly tested and carefully packed at the factory. Once the camera shipment is accepted for delivery, the carrier assumes full responsibility for its safe arrival. Should you receive your shipment with any damage—concealed or apparent—please contact the carrier at once. The carrier will instruct you on how to initiate a damage claim. If a visual inspection reveals damage upon receipt, it must be noted on the freight bill or express receipt and the notation signed by the carrier's agent. Failure to do so can result in the carrier refusing to honor the claim.

To return your camera to DVC for service, you must first contact the DVC Customer Service Department in the United States at 512-301-9564 and request a Return Material Authorization (RMA). Returns will not be accepted without an RMA. See Section 8 for details.

3. Equipment Supplied

The following is a list of equipment that may be supplied with the DVC-16000 camera, depending on your order configuration:

- DVC-16000 camera
- Camera Link or Gigabit Ethernet host interface board
- Camera Link or Gigabit Ethernet cable
- Regulated power supply
- Line cord with plug for country of service
- DVC software CD

3.1. Important safety information regarding the power supply

Dangerous voltage exists within the power supply. Do not tamper with or open the supply under any circumstances. Doing so may expose lethal voltage to personnel and will void the warranty.

3.2. Optional items

The following items may be ordered from authorized DVC dealers and are ***not*** typically supplied with the camera:

- Lenses or other optical elements
- Third-party image analysis software.

4. Installation

4.1. Host computer requirements

4.1.1. Operating system:

Windows XP or Windows Vista

4.1.2. Hardware, Camera Link and Gigabit Ethernet configurations:

At least a 2 GHz Pentium 4 processor, 2GB RAM, 10GB of free hard drive space, an available slot for the interface board, and a graphics card with at least 128 MB of video RAM and OpenGL ™ hardware support.

4.2. Installing the Gigabit Ethernet or Camera Link host interface board

Follow the instructions included with the board

This host interface board contains sensitive electronic devices that can be damaged by static discharge. Use appropriate static control methods when removing the board from the antistatic shipping bag and when installing it into the host computer.

4.3. Installing the Software

Place the DVC Software installation CD in the CD or DVD drive. Launch the installer, which will guide each installation step.

4.4. Installing the camera hardware

This camera contains sensitive electronic devices that can be damaged by static discharge. Use appropriate static control methods when handling the camera. Avoid contact with connector pins when cables and plugs are removed.

- Mount the camera in the desired location

  IMPORTANT: To avoid dust accumulation on the CCD sensor, do not remove the protective lens mount cap until ready to mount the camera to the optical system. The cap should be replaced whenever the camera is removed from the optical system
- Connect the 9-pin power supply connector to the back of the camera and secure it with the thumbscrews, finger-tight
- Connect the camera to the host with the supplied interface cable and secure it at both ends.
- Connect the power supply line cord to the mains
- Switch the power supply on

5. Camera Functions

The DVC-16000 is a versatile, high-performance digital camera with functions tailored to scientific and industrial markets. It is capable of both high-speed readout (40 MHz pixel rate) and low-noise readout (20 MHz pixel rate), both at 12-bits. Readout can be configured for single-channel or dual-channel operation. In the dual-channel mode, the KAI-16000 is split into two halves, which are read simultaneously. This approximately doubles the frame rate of single-channel readout at a given frequency.

The DVC-16000 has five basic operating modes described in detail below. Each mode can be operated at either 20 or 40 MHz and can support binning and region of interest.

All operational modes are initiated by a trigger signal. In the case of continuous modes, the trigger initiates the stream and the camera continues to run in streaming mode until explicitly disabled. The edge-triggered, single-frame mode produces one exposure in response to the leading (default: falling) edge of the trigger signal. Finally, in bulb mode, the camera exposes for the duration of the trigger pulse, beginning on the leading (default: falling) edge and ending on the trailing edge. Readout occurs immediately after the trailing edge.

The trigger signal can have three different sources: the external, TTL trigger via the auxiliary connector (see appendix B), the software-controlled trigger via a hard-wired Camera Link camera control line, or

the software-controlled through camera trigger command, via the Camera Link serial port. Developers should consult the DVC Camera API documentation for further information on the software-controlled triggers.

If the TTL, external trigger is used, the trigger signal must be active-low. The trigger point is the high-to-low (leading edge) of the trigger signal.

5.1. Operating speed and single/dual port option

The DVC-16000 is capable of operating at pixel rates of 20MHz and 40MHz and with single or dual-port options as described above. All camera functions (e.g. exposure mode, binning, ROI, etc.) are operational at either speed, subject to the limitations below.

5.1.1. 20 MHz operation

20MHz operation gives the user the maximum dynamic range, minimum noise floor, and lowest-power operation. Dynamic range refers to the maximum signal swing under which the camera meets performance specifications, and it is expressed in the maximum number of captured electrons on the CCD. At 20MHz, the DVC-16000 is capable of approximately 30,000 electrons dynamic range.

5.1.2. 40 MHz operation

40MHz operating speed provides the user with the highest capture frame rates at the expense of slightly higher noise and power dissipation. Because of amplifier limitations on the KAI-16000 CCD, the DVC-16000 is capable of approximately 20,000 electrons dynamic range at 40 MHz.

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5.1.3. Single-port and dual-port options

The DVC-16000 is capable of readout via a single port (all 16 million pixels read out through a single 12-bit channel) or dual-port in which the image is split down the middle in the “slow scan” direction and each half is read out simultaneously, using two 12-bit channels. The port options are available in both 20 MHz and 40 MHz, and for all operational modes. Dual-port operation can result in slight signal mismatch between the two image halves, due to differences in the signal path components. This can be easily compensated for in most applications.

5.2. Operational modes

The following section describes the distinct operating modes of the DVC-16000 cameras. Users of DVCView software will find many of these modes seamlessly integrated together to make operation of the camera as easy as possible. However, developers have full control of these modes via the DVC camera API.

Refer to **Appendix A** for exposure timing diagrams.

5.2.1. Continuous, overlapped exposure mode with electronic shuttering

This mode operates the CCD in a “video” mode, in which the previous exposure is being read out while the current exposure is underway. Once initiated via trigger, the camera operates continuously in this fashion until halted by the host computer.

Exposure is controlled using “electronic shuttering.” Depending on the exposure setting, electronic shuttering inhibits the CCD exposure during a specific portion of the readout

interval. Referring to the first figure in appendix A, the shorter the desired exposure, the longer the inhibition of exposure during the readout of the previous frame. Regardless of exposure time, frame rate remains constant. The maximum exposure time in this mode is the time required to read out one frame, and that frame time depends on the pixel rate, ROI, and binning settings.

Exposure range (full-resolution—without binning or Region-of Interest):

20MHz Single-Tap Readout: Increments of 271 microseconds, ranging from 271 microseconds to 905 milliseconds.

20MHz Dual-Tap Readout: Increments of 148 microseconds, ranging from 148 microseconds to 494 milliseconds.

40MHz Single-Tap Readout: Increments of 146 microseconds, ranging from 146 microseconds to 488 milliseconds.

40MHz Dual-Tap Readout: Increments of 85 microseconds, ranging from 85 microseconds to 282 milliseconds.

5.2.2. Continuous, overlapped, extended-exposure mode

In this mode, exposure and readout are overlapped, but the exposure ranges from one frame-time (time taken to read out entire frame) to many seconds. This mode is typically used if intermediate exposure times are desired but with the fastest frame rate possible. Once initiated via trigger, the camera operates continuously in this fashion until it is halted by the host computer.

Exposure range (full-resolution— without binning or Region-of Interest):

20MHz Single-Tap Readout: Increments of 271 microseconds, ranging from 905 milliseconds to > 5 hours.

20MHz Dual-Tap Readout: Increments of 148 microseconds, ranging from 494 milliseconds to > 2 hours.

40MHz Single-Tap Readout: Increments of 146 microseconds, ranging from 488 milliseconds to > 2 hours.

40MHz Dual-Tap Readout: Increments of 85 microseconds, ranging from 282 milliseconds to > 1 hour.

5.2.3. Edge-triggered exposure (single frame capture) mode

Edge-triggered exposure mode enables the camera to initiate an exposure immediately upon the leading (falling) edge of the external or Camera Link control lines, with an exposure time set by software. Alternatively, the exposure can be initiated by the host via the DVC API. The exposure and readout sequence is the same as the non-overlapped, continuous mode and has the same exposure range, except only one frame is generated. Once the readout of that frame has finished, the camera returns to the armed state, awaiting the next trigger edge.

If subsequent trigger pulses occur faster than the combined exposure and readout time, any trigger received during the exposure or readout time will be ignored, as illustrated in appendix A.

Exposure range (full-resolution— without binning or Region-of Interest):

20MHz Single-Tap Readout: Increments of 271 microseconds, ranging from 271 microseconds to > 5 hours.

20MHz Dual-Tap Readout: Increments of 148 microseconds, ranging from 148 microseconds to > 2 hours.

40MHz Single-Tap Readout: Increments of 146 microseconds, ranging from 146 microseconds to > 2 hours.

40MHz Dual-Tap Readout: Increments of 85 microseconds, ranging from 85 microseconds to > 1 hour.

5.2.4. Bulb (pulse-width exposure) mode

The term "bulb" mode is borrowed from photography, denoting a camera setting in which the shutter stays open as long as the shutter button is depressed. Bulb mode in the DVC-16000 is analogous in that the CCD exposes as long as the trigger signal is asserted (a low logic level on the external trigger or a low command on the Camera Link CC1 control line). Upon the rising edge of the trigger signal, readout of the exposure is initiated. Maximum exposure time is indefinite, although dark current will set the practical exposure time limit, depending on the operating temperature and the tolerance of the application to dark current pattern noise.

Exposure range:

20MHz or 40MHz Readout: 5 microseconds minimum. Maximum limited by dark current and particular application.

5.3. Binning

Binning is the process of summing adjacent lines and/or pixels in order to increase dynamic range, sensitivity, or both. Binning can either be accomplished on the CCD itself by summing the collected charge (on-chip binning) or in software, after A/D conversion. On-chip binning can result in slightly lower noise relative to software binning, under certain circumstances. Because fewer lines are actually read out when binning vertically, on-chip binning in the vertical direction can produce a significant increase in frame rate with increasing binning ratios. However, because the clocking cannot be accelerated in the horizontal direction, horizontal binning provides no such speed increase.

In all modes of operation, the DVC-16000 is capable of arbitrary on-chip binning (2x, 3x, 4x, 5x…21x,…) in the vertical direction, and 2x, 3x, and 4x on-chip binning in the horizontal direction. As vertical binning increases, anti-blooming control decreases, so the user must control image illumination more carefully while binning. However, blooming does not cause any damage to the camera.

As the binning factor increases, the CCD vertical registers are driven faster. This naturally causes more heating of the CCD and driving electronics. Since dark current generation increases

with CCD die temperature, a noticeable increase in CCD dark current can occur at very high binning factors.

5.4. Region of Interest

Arbitrary, on-chip vertical Region of Interest (ROI) is fully supported on the DVC-16000 cameras. When ROI is enabled, the regions above and below the region of interest are “dumped” as fast as the CCD allows. The region of interest itself is read out normally. Dumping unwanted lines outside the ROI can significantly increase the readout rate of the camera. DVCView software provides interactive, graphical ROI selection, and the DVC camera API provides developers with full ROI control. On-chip horizontal ROI is not available. Simultaneous binning and ROI is fully supported.

As in binning, the CCD vertical registers are driven faster when the region of interest is reduced. Dark current can increase during operation with small regions of interest.

6. CCD phenomena

The Kodak KAI-16000 CCD is a high-performance image sensor with very good characteristics over a wide operating range. To be as versatile as possible, the DVC-16000 camera exploits as much of the CCD capability as possible and provides the user a great degree of control over the CCD functions. As a result, it is possible to observe some interesting, low-level CCD phenomena under certain extreme conditions.

6.1. Blooming

Blooming is the result of charge spillover in the vertical transfer regions when the signal greatly exceeds saturation. The DVC-16000 provides anti-blooming control, which suppresses blooming under most imaging conditions. If signal levels are extreme and such high signal levels cover a large percentage of the field of view, blooming may occur. The result is jagged, vertical bright streaks running below such regions. In general, anti-blooming performance decreases with increasing binning ratios.

6.2. Smear

Smear is inherent to interline CCD sensors such as the KAI-16000. It is the result of transferring image charge out of the pixels and into the adjacent vertical charge-transfer registers while photons strike the CCD. Though the vertical charge-transfer registers are covered with a light shield, unwanted signal can be introduced into them either by small amounts of light leaking under the light shield or by signal electrons diffusing into the transfer region from the adjacent pixels.

Smear is typically noticed during very short exposure times, when an extremely high light intensity is incident on the CCD. The result is regions of elevated signal level extending above and below very bright regions. Kodak interline CCDs exhibit very low smear levels, and smear should not be noticeable under normal operating conditions.

7. Maintenance

IMPORTANT WARRANTY INFORMATION

There are no user-serviceable parts inside the camera. Removing the rear cover of the camera without express authorization from DVC Company will void the camera warranty.

DVC professional cameras are manufactured in a clean environment. Before shipping, each camera is tested to assure that it meets stringent specifications for cleanliness and quality.

7.1. Cleaning Guidelines

Frequent lens changes, especially without careful attention to contaminants, can allow debris to accumulate on the infra-red blocking filter, CCD, and lens surfaces. Therefore, DVC Company provides the following guidelines for maintenance of these components.

To minimize the need to clean the optical surfaces, do not remove the protective lens mount cap shipped with the DVC-16000 camera until you are ready to mount the camera to the optical system.

CAUTION: Extreme care should be taken to avoid exposing the CCD faceplate unless absolutely necessary. Fingerprints or other evidence of contact with the CCD faceplate may void the warranty.

7.1.1. Cleaning the lens or optical assembly

Please follow the lens manufacturer's recommendations for cleaning. DVC Company is not responsible for any damage caused to a lens or optical assembly caused by customer cleaning or misuse.

To ensure optimum image quality with any DVC camera, do not remove the protective lens-mount cap until ready to mount the camera on the application. If the camera is removed from the application, immediately replace the cap. Doing so will keep dust and other contaminants from accumulating on the optical surfaces. In addition, please note the following model-specific guidelines.

7.1.2. Cleaning the infra-red filter (if included)

The DVC-16000 is available with an infra-red filter within the F-mount, which is visible when the lens is removed. This filter blocks invisible, near-infra-red light from reaching the CCD sensor. This is desirable in most applications where the camera is imaging in the visible spectrum.

7.1.2.1. What must I do before cleaning the infra-red filter?

Do not remove the filter from the camera.

First, remove the lens and carefully examine the filter in a clean location under a strong, direct light. Try to determine if the contaminants are a few dust particles, oily smudge (such as fingerprints) or both.

7.1.2.2. What if the contamination is only a few dust particles?

Use a CLEAN, DRY (preferably brand-new), camel hair lens cleaning brush (such as those used by photographers) to gently wipe the particles off of the filter.

7.1.2.3. What if the contamination includes a smudge?

The filter is a high-quality, coated optical component and should be treated with extreme care. Scratches, chemical contamination, or other damage due to improper cleaning may void the warranty.

- Remove the camera from the optical assembly and bring the camera to a clean, dry location where it is safe to use flammable solvents (please see caution below)
- Use a CLEAN, DRY (preferably brand-new), camel hair lens cleaning brush (such as those used by photographers) to gently wipe the particles off of the filter.
- Re-examine the filter after removing the dust. If a smudge is still visible, proceed by dipping a clean, lint-free cotton swab in ethyl or isopropyl alcohol. The swab should be saturated, but not dripping.
- Carefully draw the swab once across the surface, then rotate the swab 180 degrees to expose the fresh surface and draw it across the filter surface again. Be careful not to pool alcohol on the glass surface.
- Re-examine once again and repeat the process once, if necessary.

If contamination continues to be a problem, please call DVC Customer Service for assistance.

CAUTION: ethyl and isopropyl alcohols are highly flammable! Do not use near extreme heat, arcing electrical equipment (such as space heaters) or open flame! Use only with proper ventilation. Follow all safety instructions provided by the manufacturer of the alcohol product.

7.1.3. Infra-red filter removal and installation

If greater near-infra-red sensitivity is desired, the infra-red filter can be removed. It is important to note that removal of the IR filter can allow debris to collect on the CCD faceplate. **Please contact the factory before attempting to remove the infra-red filter**.

7.1.4. Cleaning the CCD faceplate

CAUTION: The CCD faceplate is a high-quality, coated optical surface and should only be cleaned by authorized, DVC personnel.

If contamination of the CCD faceplate is suspected, DVC strongly recommends returning the camera to the factory for professional cleaning.

Scratches, chemical contamination, or other damage due to improper cleaning may void the camera warranty.

8. Warranty and After-Sale Service

DVC Company warrants equipment manufactured to be free from defects of material and workmanship. Any part or parts will be repaired or replaced when proven by DVC examination to have been defective within two years from the date of shipment to the original purchaser. Any warranty repairs will be performed at the factory or as otherwise authorized by DVC, in writing. Transportation charges to DVC shall be pre-paid by purchaser.

This warranty does not extend to DVC manufactured equipment subjected to misuse, accident, neglect or improper application. Nor does the warranty extend to DVC manufactured equipment that is repaired or altered by anyone other than DVC or those authorized by DVC, in writing. Products manufactured by other companies, but re-sold by DVC such as lenses, optical and electro-optical assemblies, power supplies, cables, image processor boards and software are warranted by the original manufacturer.

This warranty is in lieu of all other warranties expressed or implied. DVC shall not be liable for any collateral or consequential damages.

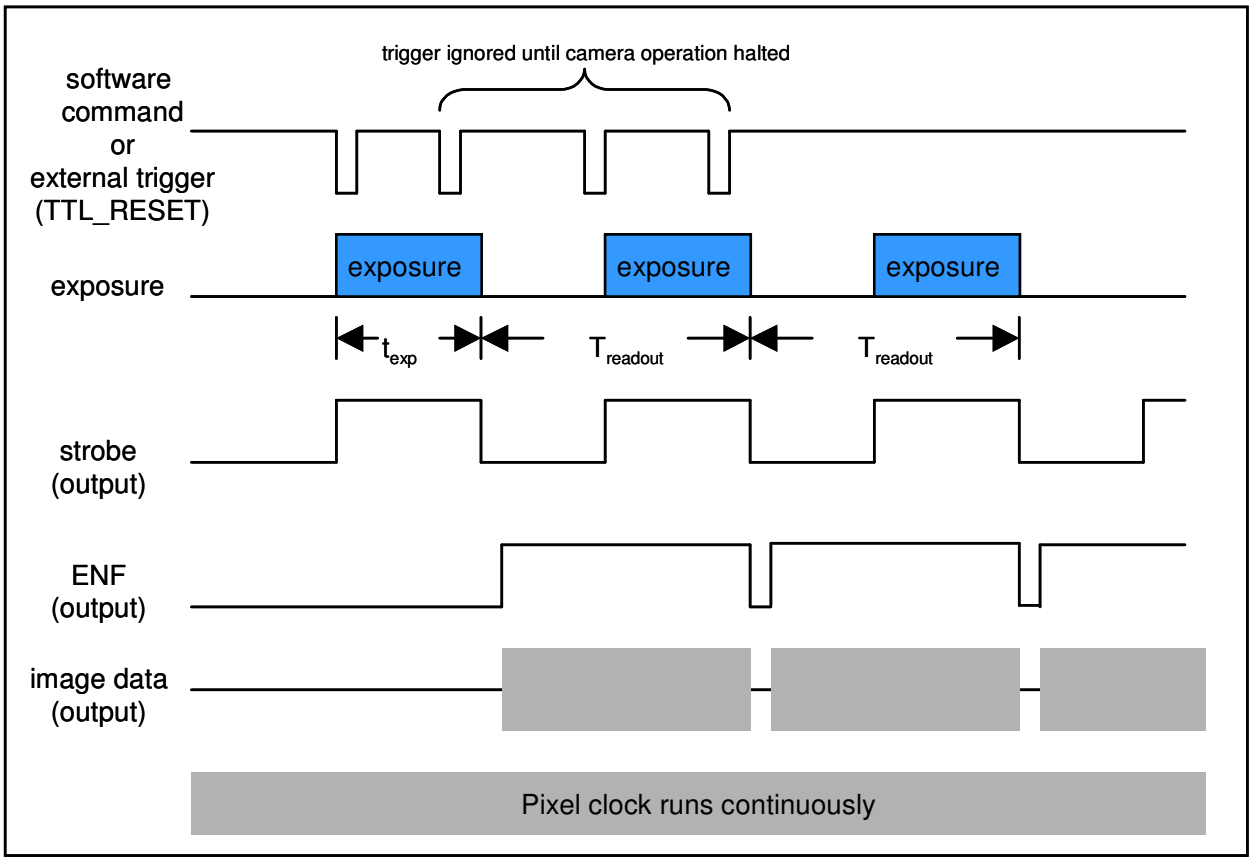
A Return Material Authorization (RMA) Number must be obtained from DVC prior to returning any item for warranty repair or replacement.

9. Copyright Information

Appendix A: Exposure Timing Diagrams

Continuous, overlapped exposure mode with electronic shutter

In the continuous, overlapped exposure mode, the camera remains in an idle state until the falling edge of the trigger. A first exposure is made, followed by the typical, interline CCD overlapped exposure/readout cycle. Electronic shuttering allows the exposure to be adjusted via software control without altering the frame rate of the readout. Any further triggers while the camera is operating continuously are ignored. The camera will remain in this continuous operation until disabled through software command. It can then be re-armed for another trigger event.

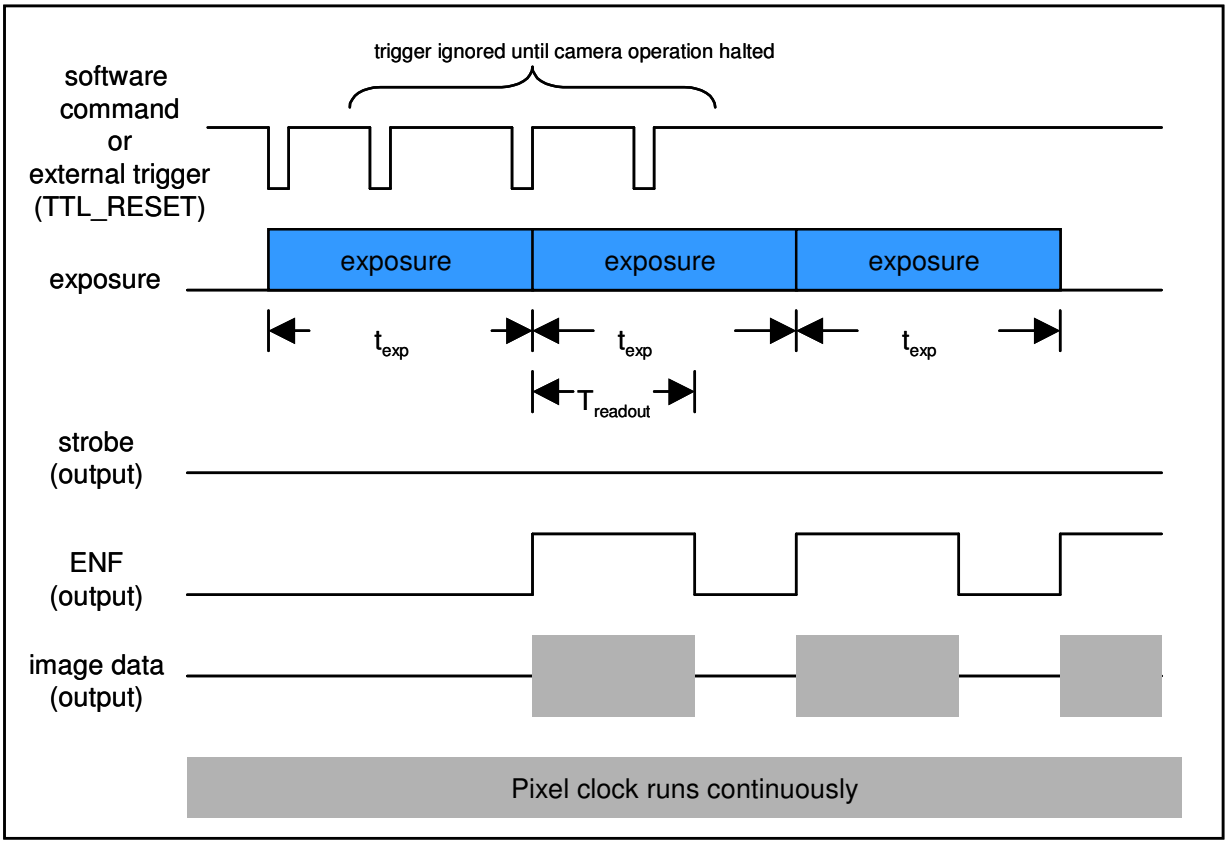


Continuous, overlapped exposure mode with electronic shutter. Strobe pulse occurs only if enabled.

Continuous, overlapped, extended-exposure mode

This mode is similar to the overlapped, electronic-shuttered exposure mode except that the electronic shutter is not enabled and the exposure times are greater than one readout cycle (frame time). As a result, readout frame rate will decrease as exposure time is increased, but the overlapping exposure and readout provide the maximum frame rate for a given exposure time. This mode also offers much longer integration times than overlapped, electronic-shuttered exposure mode.

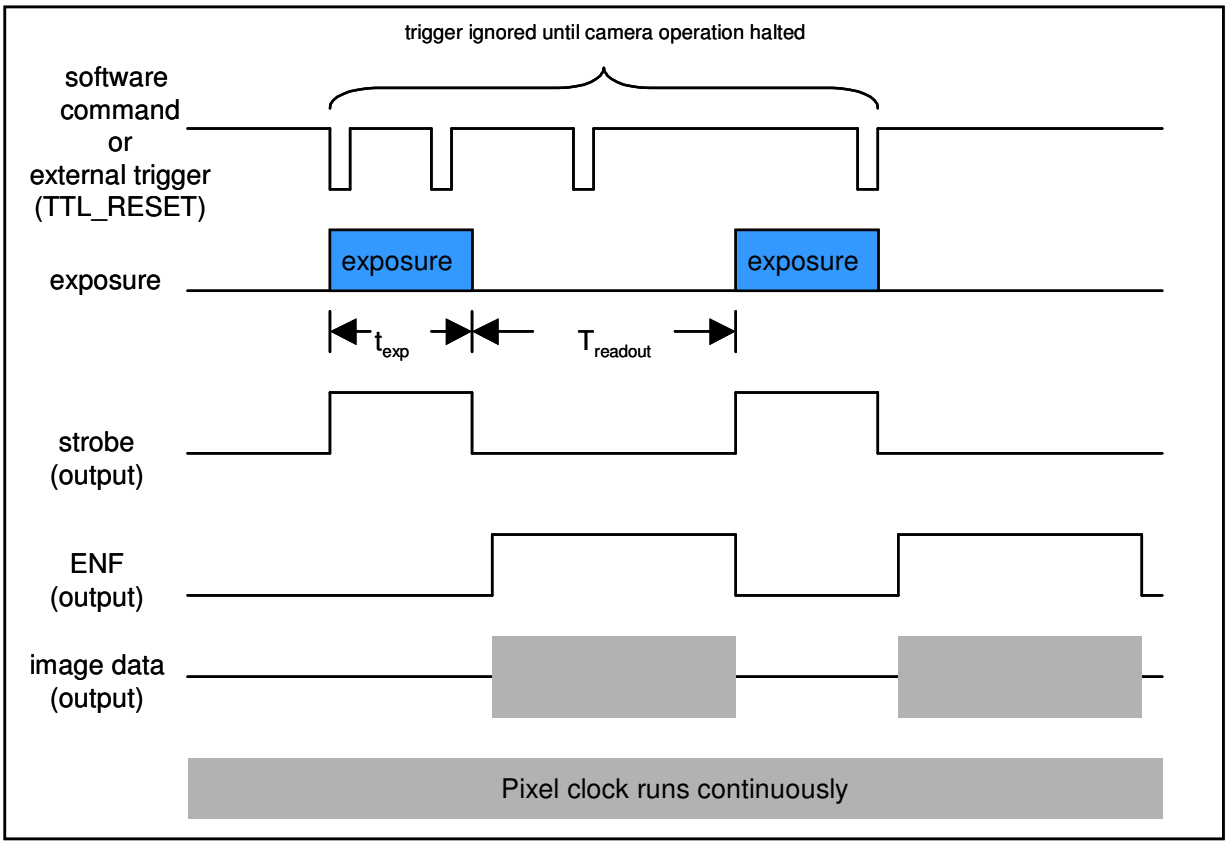
Any further triggers while the camera is operating continuously are ignored. The camera will remain in this continuous operation until disabled through software command. It can then be re-armed for another trigger event.



Continuous, overlapped, extended exposure mode. Strobe pulse is disabled due to continuous nature of exposure

Continuous, non-overlapped exposure mode

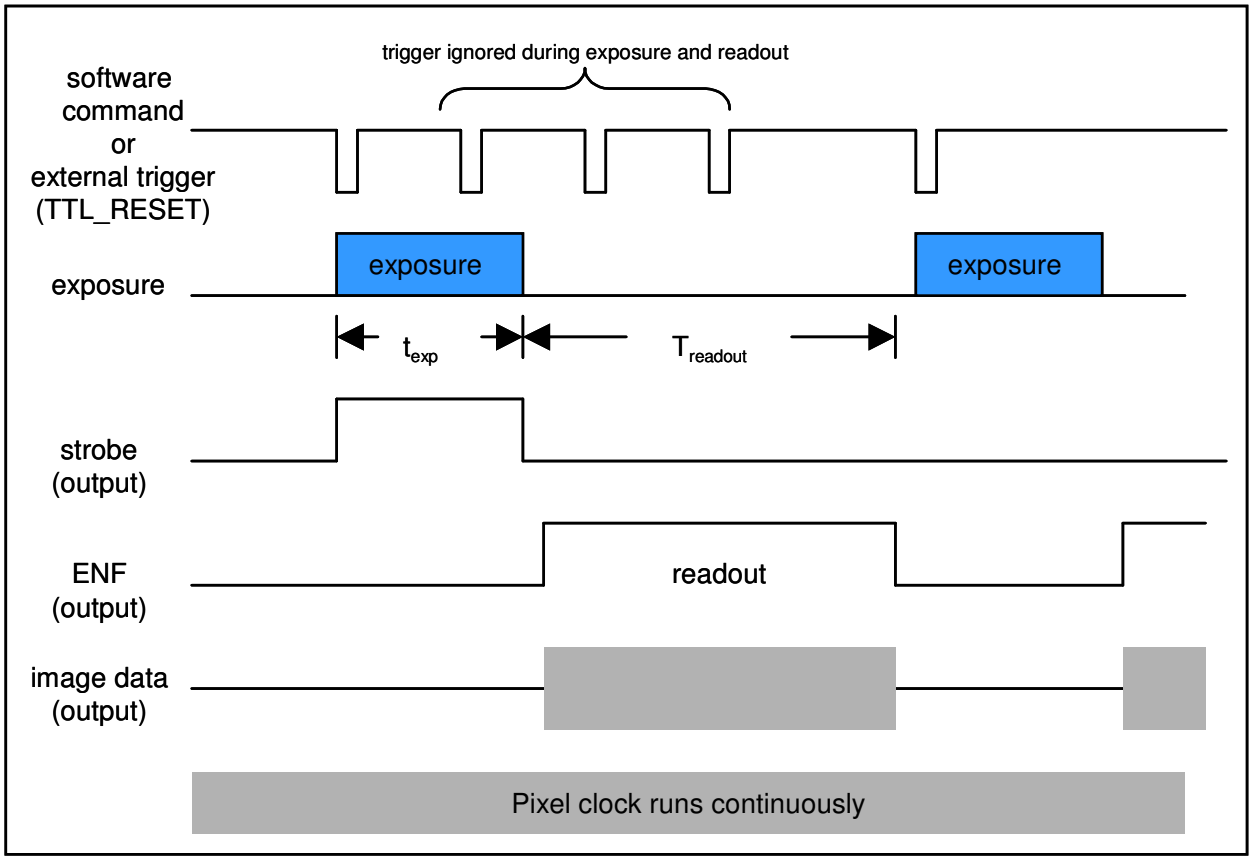
This mode is similar to the overlapped exposure mode except that the exposure and readout periods are separate and do not overlap. As a result, for a given exposure time, readout frame rates will be lower than that of overlapped exposure and will also decrease as exposure time is increased. Any further triggers while the camera is operating continuously are ignored. The camera will remain in this continuous operation until disabled through software command. It can then be re-armed for another trigger event.



Continuous, non-overlapped exposure mode. Strobe pulse occurs only if enabled.

Edge-triggered exposure (single frame capture) mode

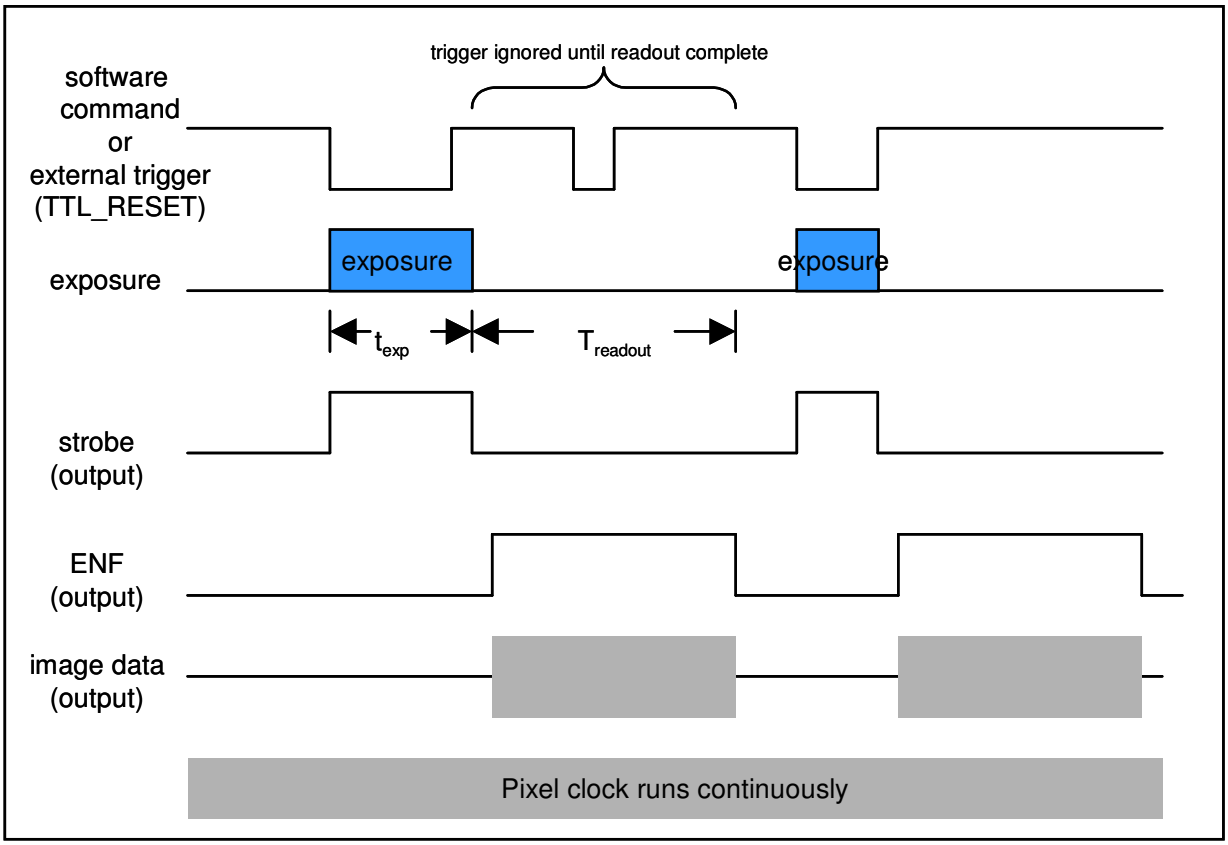
Edge-triggered exposure mode operates almost identically to the first frame of the non-overlapped continuous mode except that instead of continuing to run, the camera returns to the armed state, waiting for another trigger. Exposure is controlled by software.



Edge-triggered exposure mode. Strobe pulse occurs only if enabled.

Bulb (pulse-width exposure) mode

Bulb mode allows the camera exposure to be controlled by the external trigger signal. The leading edge of the trigger signal initiates the exposure, and the camera will continue to expose until the trailing edge of the trigger, as shown. The readout sequence begins immediately after the trigger signal trailing edge, and at the end of readout, the camera returns to the armed state, awaiting the next trigger. Any trigger activity during the readout sequence is ignored.



Bulb (pulse-width exposure) mode. Strobe pulse occurs only if enabled.

Appendix B: description of DVC-16000 auxiliary and power supply connectors

Auxiliary connector

The auxiliary connector on the DVC-16000 camera allows the user access certain camera control and internal status signals. The following section describes each signal.

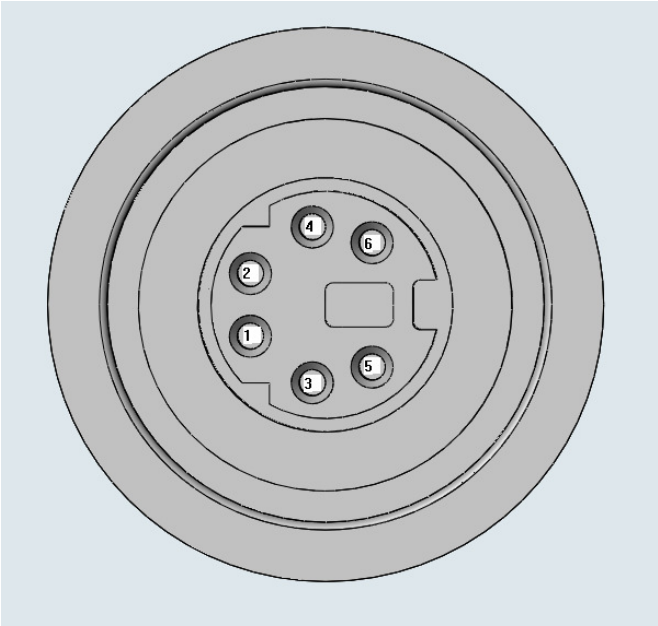


Illustration of the auxiliary connector on the rear of the DVC-16000 camera

Auxiliary Connector Pin Signal list:

Pin #	Signal
1	ENL (Output)
2	DIFF_RESET_OUT (Output)
3	TTL_RESET (Input)
4	GND
5	ENF (Output)
6	STROBE/INT-PULSE (Output)

Pin 1, ENL

ENL refers to “Enable Line.” It is an active-high TTL signal and is asserted during the valid pixel period on each line, as shown in the diagrams in Appendix A. It returns low during the inter-line period between each line and during the inter-frame period between each frame.

Pin 2, DIFF_RESET_OUT

This pin is an active-low TTL signal that is the buffered version of the Camera Link CC1 signal. The CC1 signal, driven from the host, is one of the software-controlled

trigger signals for the camera as described in Appendix A. The CC1 signal is brought out of the camera as DIFF_RESET_OUT to allow users to trigger other devices. DIFF_RESET_OUT is labeled INPUT_1 on older DVC cameras and on the Mini-DIN-to-BNC cable accessory sold by DVC.

Pin 3, TTL_RESET

TTL_RESET is a TTL input used to trigger exposures. It functions identically to the Camera Link CC1 signal. TTL_RESET is also labeled VRST_INT on older DVC cameras and on the Mini-DIN-to-BNC cable accessory sold by DVC.

Pin 4, GND

This is the electrical ground for the camera.

Pin 5, ENF

ENF refers to Enable Frame and is a TTL output that is high during active readout lines. EN_FRAME remains high throughout the active readout and returns low between frames.

Pin 6, STROBE (and programmable output)

STROBE is a TTL output that, if enabled, is high during the actual sensor exposure time in certain modes. Refer to the diagrams in Appendix A for details on STROBE operation with respect to the exposure interval in each mode. STROBE is typically used to synchronize an external flash lamp or other device with the camera.. The STROBE signal can also be configured as a programmable output that can be set high or low from the host computer. Refer to the DVC API documentation for details.

Power supply connector pin assignments

The power supply connector is a standard, DB-9 male connector with the following pin assignments:

Pin No.	Signal Name	Signal Name	Pin No.
6	GND	+5 VDC, 250mA	1
7	Reserved	+4.8VDC, 1250mA	2
8	GND	-15 VDC, 250mA	3
9	Reserved	Reserved	4
		+15 VDC, 250mA	5